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Quaternary Geology
Brampton Area

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P.F. Karrow

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Contents

Abstract vii

Introduction 1
- Location and Access 1
- Previous Work 1
- Field Work 2
- Acknowledgements 2

Physiography 3
- Relief 3
- Drainage 3
- Physiographic Classification 3

Paleozoic Geology 7
- Ordovician 7
- Silurian 7
- Economic Geology 7
- Structural Disturbance 8

Quaternary Geology 10
- Geomorphology 10
  - Bedrock Topography 10
    - Bedrock Scarps 10
    - Buried Valleys 10
    - Escarpment Re-entrant Valleys 11
    - Topography and its Influence on the Distribution of Bedrock Formations 11
  - Palimpsest Topography 12
  - Till Plains 12
    - Wentworth Till Plain 12
    - Halton Till Plain 12
  - Drumlins and Flutings 13
  - Moraines 13
    - Acton Moraine 14
    - Cheltenham Moraine 14
    - Kelso Moraine 15
    - Trafalgar Moraine 15
  - Kames 15
  - Eskers 15
  - Kettles 16
  - Outwash Plains 16
  - Meltwater Channels 17
  - Lake Plains 17
  - Abandoned Shorelines 18
  - Deltas 18
  - Stream Terraces and Flood Plains 19
  - Swamps and Bogs 19
  - Lake Ontario Shoreline 20
- Stratigraphy 20
  - Valley Exposures 20
    - Sixteen Mile Creek 20
    - Credit River 20
    - Etobicoke and Mimico Creeks 20

Humber River 20
Stratigraphic Nomenclature 21
Escarpment Crevice Deposits 21
York Till 22
Sunnybrook Till 23
Wentworth Till 24
Newmarket Till 24
Maple Formation 24
Halton Till 26
Late Glacial Glaciofluvial Deposits 27
Glaciolacustrine Deposits 28
Alluvial Deposits 29
Organic Deposits 30
Lake Ontario Deposits 31
Historical Geology 31
Economic Geology 32
Agricultural Soils 32
Sand and Gravel 32
Water Supply 33
Peat 33
Clay 34
Engineering Geology 34
Appendix 1: Descriptions of Measured Sections 35
Appendix 2: Logs of Cores from Holes Drilled for the Ontario Geological Survey 43
Appendix 3: Locations of Sample Sites Other Than Those Described in Appendix 1 48
Appendix 4: Analytical Results 51
References 55
Metric Conversion Table 59

FIGURES

1. Location of study area 1
2. Physiographic regions within the study area 4
3. Bedrock geology of southern Ontario 6
4. Areas of influence of major glacial lobes in the vicinity of the study area 11
5. Location of major moraines in the vicinity of the study area 13
6. Location of glacial lakes mentioned in the text 17
7. Stratigraphic and time-distance relationship of tills and ice advances between Toronto and Woodstock, Ontario 21

PHOTOS

1. Hand tools used during the field survey 2
2. Queenston Formation outcrop in the west bank of Sixteen Mile Creek, south edge of map area 7
3. Airphoto of pop-up linear ridge near intersection of Winston Churchill Blvd. and Queen Elizabeth Way 8
4. Small anticline in Georgian Bay Formation along Spring Creek, west of Pearson International Airport 9
5. Small fold (pop up) in Georgian Bay Formation, quarry of former Cooksville Brick Company 9
6. Irregular surface of Amabel Formation at Dufferin Aggregates quarry 11

7. Pothole eroded in Amabel Formation by glacial meltwater, Dufferin Aggregates quarry 11
8. Gently undulating Halton Till plain northeast of Georgetown 13
9. Airphoto showing mottled Trafalgar moraine and flutings in till plain south of Streetsville 14
10. Airphoto showing distribution of ice-block depressions (kettles) along Brampton esker, north of Brampton 16
11. Dissected frontal slope of a Credit River delta formed in glacial Lake Peel, 2 km south of Huttonville 19
12. Large cut (measured section B-2633) east of Mountainview Road in northern Georgetown exposing Halton Till over glaciolacustrine clay of the Maple formation 25
13. Glaciolacustrine clay at B-2633 25
14. Detail of disturbed bedding in glaciolacustrine clay at B-2633 25
15. Fault in glaciolacustrine clay at B-2633 25
16. Foreset bedding in ice-contact (?) gravels of the Maple formation at field station 2646, Glen Williams 26
17. Detail view of poorly sorted, subangular gravel of the Maple formation at field station 2646 26
18. Gravel pit in planar, horizontally bedded outwash gravel southwest of Limehouse 28
19. Well-developed bedding in outwash gravel southwest of Limehouse 28
20. South bank of Credit River at Erindale exposing glacial Lake Iroquois bar sand and gravel overlying Ordovician shale 29
21. Older alluvial sand and gravel overlying till in south bank of Credit River near Meadowvale 29
22. Young alluvium on flood plain of Etobicoke Creek near Burnhamthorpe Road 30
23. Early Woodland projectile point found near Highway 401 and Kennedy Road 32
24. A former gravel pit, now covered by housing, situated on the Brampton esker 33
25. Boulder of Precambrian gneiss located in front of the Parliament Buildings, Toronto, found west of Speyside 33

TABLE

1. Vertebrates in Niagara Escarpment crevices 22

GEOLOGICAL MAP

Map 2223 – Quaternary Geology of the Brampton Area ..... back pocket

Abstract

The Brampton area is located west of Toronto and northwest of Lake Ontario. There are extensive areas of shallow drift, with the north-trending Niagara Escarpment forming the most striking topographic feature near the western edge of the area. West of the escarpment, a rough bedrock surface underlain by Silurian dolostone is patchily covered by swamps, bouldery till and ice-contact gravels.

In the area east of the Niagara Escarpment, underlain by Ordovician shale, a few buried valleys 30 to 60 m deep dissect the bedrock surface. The largest of these correspond to the modern Credit River and Humber River valleys, which drain the central and northeastern parts of the map area, respectively. The extensive till plain east of the escarpment is an undulating surface of low relief subdued by lake sediments of glacial lakes Peel and Iroquois.

Sparse stratigraphic information suggests the presence of Illinois York Till, Early Wisconsin Sunnybrook Till, Late Wisconsin Newmarket Till and Late Wisconsin Maple formation gravel, sand and clay, below the surface Late Wisconsin Halton Till.

Mineral production in the area is in decline because of rapid urbanization, but brick-making based on shale, and aggregate extraction based on dolostone and ice-contact and outwash sand and gravel, continue. There are few engineering problems with the Quaternary sediments in the area, but numerous bedrock pop ups and faults in the southeast suggest high *in situ* rock stresses, which have been relieved by rock deformation in postglacial time.

Introduction

LOCATION AND ACCESS

The area covered in this report is located in southwestern Ontario, northwest of the western end of Lake Ontario (Figure 1). The area extends over approximately 1120 km^2. Bounded by latitudes 43°30′N and 43°45′N, and by longitudes 79°30′W and 80°00′W, the area is covered by National Topographic Series (NTS) 1:50 000 scale sheet 30 M/12. The area is also covered by several 1:25 000 scale NTS sheets, as well as by Ontario Basic Mapping (OBM) sheets at a scale of 1:10 000.

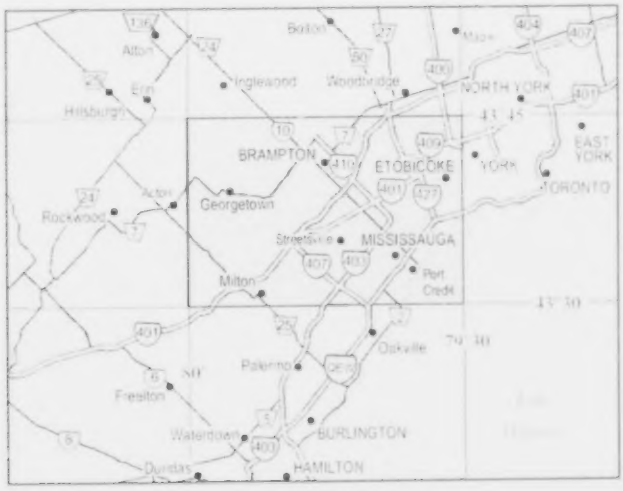
About 65 km^2 of Lake Ontario occurs in the southeast corner of the study area. The study area includes the western part of the City of Toronto. In the remainder of the study area there has been extensive municipal reorganization and the former counties of Peel and Halton are now embraced by the Peel Regional Municipality and the Halton Regional Municipality. Large rural areas, as well as rapidly growing urban areas, are embraced by the cities of Mississauga (including Streetsville and Port Credit) and Brampton, and the towns of Halton Hills (including Georgetown) and Milton. A small part of Wellington County is included in the northwest corner of the area.

Access to most parts of the area is readily available by means of the township road grid, in which many of the roads are paved. Provincial highways 10, 400, 401, 403, 407, 409, 410, 427, and the Queen Elizabeth Way (QEW) serve parts of the area. Main and secondary lines of Canadian National and Canadian Pacific railways cross the area. Access to the St. Lawrence Seaway is available on Lake Ontario but only limited shipping facilities are available at Port Credit. Major air transport facilities are available at Pearson International Airport, located in the northeast part of the study area.

PREVIOUS WORK

In spite of its location at the western edge of Toronto, the Brampton area has received little in the way of geologic study, particularly its Quaternary geology. The area is included in a regional physiographic study by Chapman and Putnam (1984). A few specific studies, such as those by Coleman on glacial Lake Iroquois (Coleman 1937a) and the north shore of Lake Ontario (Coleman 1937b), touch on the area.

Watt (1957, 1968) conducted mapping of former North York and Etobicoke townships (now part of the City of Toronto), centred on water resources investigations, which resulted in the production of maps of the Pleistocene geology at scales of 1:31 680 and 1:25 000, respectively. Similar mapping by Watt covered former Toronto and Chinguacousy townships in Peel County (now part of the Regional Municipality of Peel), but these maps and reports were never published. A compilation with added information covering Metropolitan Toronto and some adjacent areas was prepared by Sharpe (1980a) at a scale of 1:100 000 and included the eastern part of the present study area. All adjacent areas, except to the east, have been covered by systematic 1:50 000 scale mapping. Maps and reports are available for the Bolton (White 1975), Orangeville (Cowan 1976), Guelph (Karrow 1968) and Hamilton–Cambridge (Karrow 1963, 1987a) map areas. Since the completion of the present mapping, a major joint project, undertaken because of the environmental impact of the rapid population growth and development of Toronto, was launched by the Ontario Geological Survey and the Geological Survey of Canada to investigate the Oak Ridges moraine, a major linear belt of ice-marginal deposits that extends from the Niagara Escarpment near Orangeville eastward to Trenton. Although the project did not deal di-



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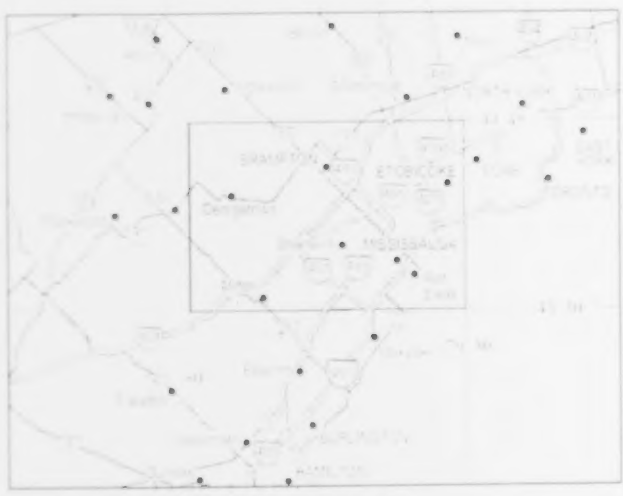

Figure 1. Location of study area.

rectly with the Brampton area, extensive drilling and geophysical investigation of its deep Quaternary stratigraphy, approaching 300 m depth, yielded reinterpretations that affect those of the Brampton area (e.g., Barnett et al. 1998; Sharpe et al. 2002). Also, studies of Toronto area environmental geology have provided many new data relevant to stratigraphic interpretation in the Brampton area (Gerber and Howard 1996; Baker, Lahti and Roumbanis 1998; Boyce and Eyles 2000). Additional specific studies will be referred to at relevant places later in this report.

Bedrock geology has received somewhat more attention. The most recent map coverage, on a regional scale, is that of Liberty (1969). The stratigraphy of the Niagara Escarpment was described by Bolton (1957). The Brampton area was mapped by Telford, Bond and Liberty (1976). Hewitt (1969) described the industrial minerals of the area, and agricultural soils have been described by Hoffman and Richards (1953, 1955), Hoffman, Matthews and Wicklund (1963) and Gillespie, Wicklund and Miller (1971). Ostry (1979) and Funk (1979) studied the hydrogeology of Oakville Creek (now called Sixteen Mile Creek), and Hickinbotham (1979) described water resources in the Region of Peel.

FIELD WORK

Systematic Quaternary mapping of the Brampton area was begun by D.R. Sharpe in 1980 (Sharpe 1980b) but was discontinued. The present mapping began in 1984 and continued on a part-time basis to completion in 1987. Progress reports (Karrow 1984a, 1985, 1986a, 1987b) and preliminary maps (Karrow 1987c; Karrow and Easton 1990) have been released previously.

Field work consisted of examining available natural exposures in stream banks and lake shorecliffs, and man-made exposures in road and railway cuts, service trenches and building excavations. This was supplemented by hand auger and probe holes at many other locations. Photo 1 illustrates some of the hand tools used during the field survey. Surface materials at least 1 m thick are shown on Map 2223 (back pocket). Field work was aided by airphotos of the area. Photos from 1954 were particularly useful in areas now disturbed and covered by urban development, while photos taken in the 1970s were generally of better quality.

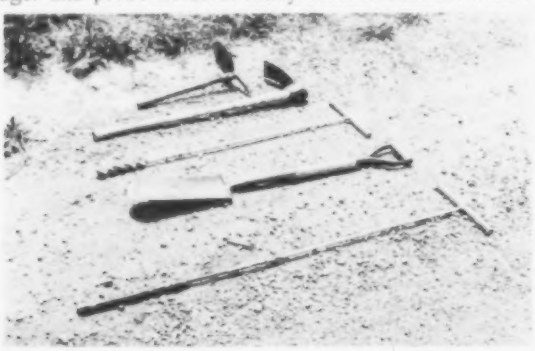

Photo 1. Hand tools used during the field survey. From upper left to lower right: trenching tool, grubhoe, soil auger, tile spade, soil probe (the soil probe measures roughly 1.5 m from handle to tip).

As mapping reached the edge of the area covered by Watt (1968), it became evident that additional data were needed to make the maps compatible. As a result, in the summer of 1987, J.A. Easton carried out extensive field work in Etobicoke and North York to delineate surface glaciolacustrine deposits and bedrock outcrops.

In 1986, several continuously cored holes were drilled in the western part of the area to provide subsurface stratigraphic information (Roumbanis and White 1986), which is generally lacking because of the scarcity of valley wall exposures. Concurrent with the field program, gas and water well and engineering bore hole data were compiled by D.C. Roumbanis to construct bedrock topography and drift thickness maps, being incorporated later into regional projects.

ACKNOWLEDGEMENTS

Field assistance over the course of mapping was capably provided by J.A. Easton, D.S. Turnbull, R.I. Kelly and E. Wright.

The Brampton area has a high population density, particularly in the eastern part, and access to private land was necessary on innumerable occasions. Residents, contractors, consultants and municipal officials were most cooperative in providing access and information, for which the author is very grateful. A.K. Watt and D.R. Sharpe provided field notes and other information resulting from their earlier work, but responsibility for the accuracy of the present map rests with the author. J. Terasmae provided section descriptions (from work by H.L. Matthews, Brock University) along valleys now mostly within Brampton and no longer accessible. N.A. Rukavina, Canada Centre for Inland Waters, provided information on offshore Lake Ontario sediments. Laboratory analyses of field samples were performed by the Geosciences Laboratories, Ontario Geological Survey, Toronto.

Physiography

RELIEF

Elevations above sea level in the area range from a maximum of 400 m in the extreme northwest corner, to 75 m at the Lake Ontario shoreline, yielding a total relief of some 325 m. Most of the area is of low relief, with the most abrupt changes in elevation being along the Niagara Escarpment. The escarpment trends generally north and lies some 2 to 4 km east of the western edge of the study area. The elevation of the escarpment crest declines gradually southward from 350 m at the north edge of the map area to 320 m on the Milton outlier at the south edge. Local relief along the escarpment varies from 15 to 60 m, consisting of vertical cliffs of cap rock and steep slopes of underlying softer formations.

Few notable valleys cross the area. Relief along the Credit River valley reaches 30 m near Georgetown and Lorne Park. The Humber River valley south of Weston reaches a similar depth. Elsewhere even the larger valleys are more commonly only about 15 m deep. Lesser valleys are commonly only 5 to 10 m in depth. Most of the remainder of the area is of very gentle relief associated with fluted to undulating till plains, lake plains and valley terraces. Slightly more rugged topography is present above (west of) the Niagara Escarpment, where a rough bedrock surface creates local knobs up to a few metres in height.

DRAINAGE

All of the area is drained by streams flowing into Lake Ontario. From west to east the principle streams are Sixteen Mile (Oakville) Creek, Credit River, Etobicoke Creek, Mimico Creek and Humber River.

The west branch of Sixteen Mile Creek enters the study area in the southwest corner at Kelso, where it is presently dammed to form a recreational lake in the Kelso Conservation Area. Downstream from there it flows through Milton and out of the area. In this 9 km course it drops about 60 m from its entering elevation of 240 m. The middle and east branches are of more significance to the drainage of the area as their tributaries head in the till plain, meltwater channels and lower escarpment slopes south of Georgetown. The numerous tributaries head at elevations varying from 330 m (middle branch) to 260 m (east branch). The middle and east branches join south of Hornby and flow out of the area at 170 m elevation east of Milton. The middle branch gradient averages about 7 m/km in its 24 km course, while the east branch gradient averages 5 m/km in its 15 km course to the junction with the middle branch.

The Credit River drains a strip of land extending diagonally northwest to southeast across the area. It enters the north edge of the study area at Cheltenham, at an elevation of 253 m. Over its 35 km course the river has an average gradient of 5 m/km. Through much of this distance it is characterized by rapids, and steep cliffs of shale form its banks; as a consequence it is a popular stream for canoeing and fishing. A middle portion, from Huttonville to Streetsville, has a lower gradient and broader valley; bedrock outcrops are absent because of the presence of an underlying buried bedrock valley. North of Georgetown, numerous minor short streams drain the lower escarpment slopes directly into the Credit River valley, which is notably asymmetrical in this portion. From Cheltenham to Georgetown the course of the river follows a former ice-marginal position west of the Cheltenham moraine and then turns abruptly eastward, parallel to the ice flow direction, to Huttonville. From Huttonville it angles southeastward to Erin Mills, southeast of which it is deflected around a glacial Lake Iroquois baymouth gravel bar, then finally continues southeast to Lake Ontario at Port Credit. Marshes border the lowest 2 km and relate to the drowning of its mouth by the long-term rising of the waters of Lake Ontario.

Etobicoke Creek enters the study area northwest of Brampton at an elevation of 256 m, flows through the city, passes the southwest edge of Pearson International Airport and continues southeast to Lake Ontario at Long Branch. The creek has an average gradient of 7 m/km over its 27 km course. Bedrock outcrops are common along its course from Brampton downstream to Lake Ontario. Mimico Creek heads along the north edge of the map area north of Brampton at 245 m elevation. It has an average gradient of 8 m/km. The creek passes east of the airport and leaves the map area along its eastern edge north of the QEW.

Only a small portion of the Humber River is within the study area, draining part of the northeast corner of the area. The west branch of the river enters the north edge of the map area at Claireville and trends eastward to join the east branch at Thistletown. The combined stream then flows southeast through Weston and leaves the area a few kilometres further south. In the lower portion, rock walls are common.

PHYSIOGRAPHIC CLASSIFICATION

The Brampton area embraces parts of 7 of the physiographic regions designated by Chapman and Putnam (1984): Niagara Escarpment; Horseshoe Moraines; Flamborough Plain; Oak Ridges Moraine; Peel Plain; South Slope; and Iroquois Plain (Figure 2). Only brief comments are made about them here as the elements comprising them are described more fully under the "Geomorphology" section of this report. The reader is referred to Chapman and Putnam (1984) for a more extensive description.

The Niagara Escarpment, the most prominent topographic feature in southern Ontario, extends as a cliff line parallel to and near the west edge of the study area. The bedrock formations forming the escarpment dip gently

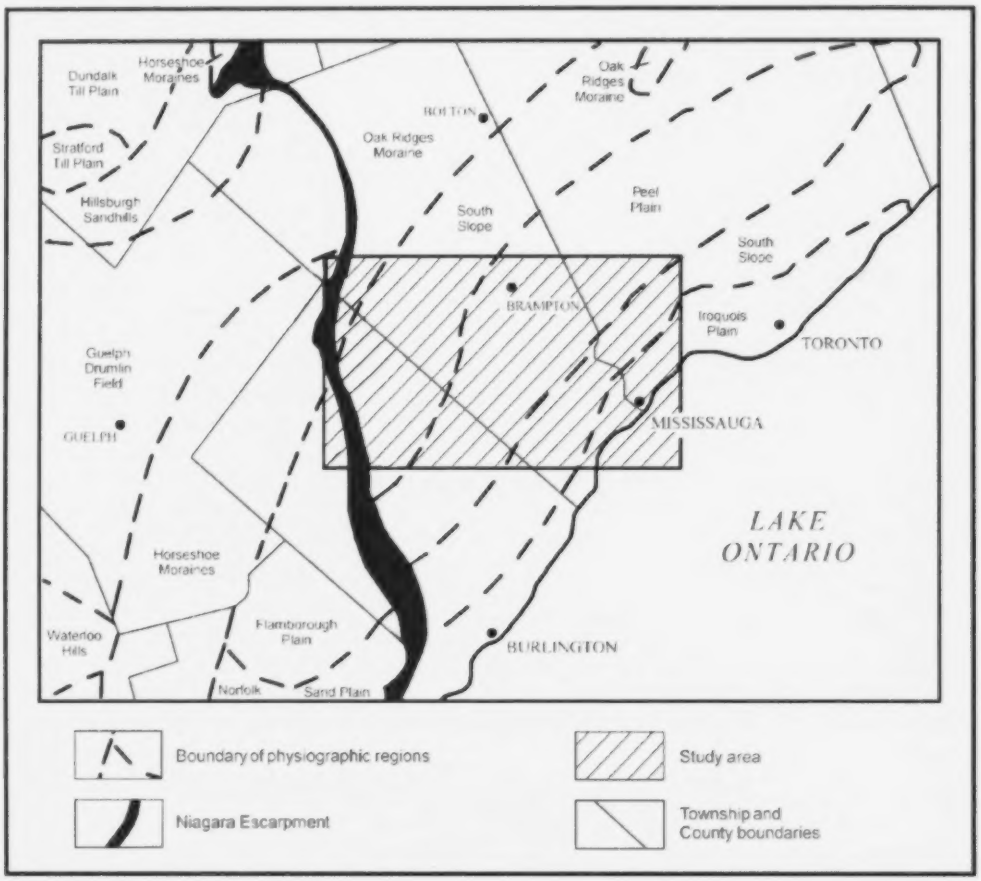

Figure 2. Physiographic regions within the study area (*adapted from* Chapman and Putnam 1984).

westward into the Michigan Basin. The escarpment trends generally north in the Brampton map area and serves to separate the Flamborough Plain region on the west from the South Slope and Peel Plain regions to the east. As described by Hewitt (1971), the Niagara Escarpment is in some parts multiple. In the Brampton area, a secondary low scarp appears at its base, formed by the basal Silurian Whirlpool Formation (sandstone) and overlying Manitoulin Formation (dolostone), which rest on the soft Queenston Formation (red shale). This lower scarp, locally referred to as the "Whirlpool Escarpment", is evident northwest of Kelso Lake; as a northward-broadening wedge southwest of Stewarttown that terminates at the reentrant at Limehouse; and as a narrow bench between Terra Cotta and Cheltenham.

Small areas of Chapman and Putnam's (1984) Horseshoe Moraines and Oak Ridges Moraine physiographic regions are included in the northwest part of the area near the Niagara Escarpment, but are not discussed further here because of their limited extent. Readers should consult Chapman and Putnam (1984) and White (1975) for more information.

Flamborough Plain is the main physiographic region west of the Niagara Escarpment. The topography is rugged in detail, formed by an irregular bedrock surface on which are superimposed a variety of small constructional glacial forms. Silurian carbonate rock outcrops are common in this region. Its ruggedness and rocky nature has prevented agricultural development; this region embraces the bulk of the forested land in the map area. This upland surface forms the highest part of the map area and slopes gradually southward following the trend of the escarpment rim. It is divided into 5 parts in the map area by valleys cut into the escarpment. One valley is located west of Limehouse and extends westward to Acton in the Guelph area (Karrow 1968). Another extends southwest from Kelso and separates the Milton outlier from the main part of the Niagara Escarpment. Most of the Milton outlier is in the Hamilton area to the south (Karrow 1987a), but its flat top forms a small isolated portion of the Flamborough Plain within the present study area. Smaller outliers are located at Limehouse (the Limehouse outlier) and southwest of Terra Cotta (the Terra Cotta outlier), also isolated from the main part of the Niagara Escarpment by valleys. (Refer to Map 2223

for locations of outliers mentioned in the text.) In the latter case, the valley has cut through the whole escarpment rock succession down to the Queenston Formation.

The Peel Plain comprises the northern and central parts of the map area east of the Niagara Escarpment and northwest of a line curving through Streetsville and Malton. This area of low relief was affected by a succession of changing levels of glacial Lake Peel, whose sediments occur sporadically in topographic lows in the till plain. As a result, the surface of this area consists of lake sediments, commonly too thin to map, or till. Dissection of its surface has only progressed to a limited degree, the valley of the Credit River being most notable. Erosion has been hindered by its gentle slopes and the common presence of bedrock at shallow depth.

The main part of Chapman and Putnam's (1984) South Slope region in the area is a belt of land trending north to northeast through Streetsville and Malton. It includes the Trafalgar moraine and a strip of fluted till plain to the east a few kilometres wide. Its southeastern boundary is the shoreline of glacial Lake Iroquois. This low-relief region is now mostly covered by urban development. Here too, bedrock is commonly at shallow depth or at the surface. Numerous minor creeks drain its steeper slopes following the trend of flutings in the till plain. The crest of the Trafalgar moraine controlled the pattern of some tributaries of the Credit River and Etobicoke Creek.

Chapman and Putnam (1984) also include a northern segment they classify as North Slope north of the Peel Plain. However, in the Brampton sheet, it is more like the Peel Plain, with its undulating till plain and thin surface lake sediments.

Finally, within the study area the Iroquois Plain comprises a strip of land 3 to 5 km wide between the glacial Lake Iroquois shoreline and the present shoreline of Lake Ontario. This essentially flat surface is marked at the landward edge by shorecliffs and valley-mouth gravel bars formed by the waves of glacial Lake Iroquois when its waters were about 45 m higher than the present Lake Ontario level. Because of subsequent glacio-isostatic crustal tilting, the shoreline rises gradually northeastward. Near the Humber River, the shoreline turns northward into a bay of glacial Lake Iroquois that extended to Weston. Much of the Iroquois Plain is dissected by streams, which occur in greater concentration in areas of deeper sands. Probably spring sapping at the contact with underlying till or bedrock contributed to this development, which is particularly prominent at Lorne Park.

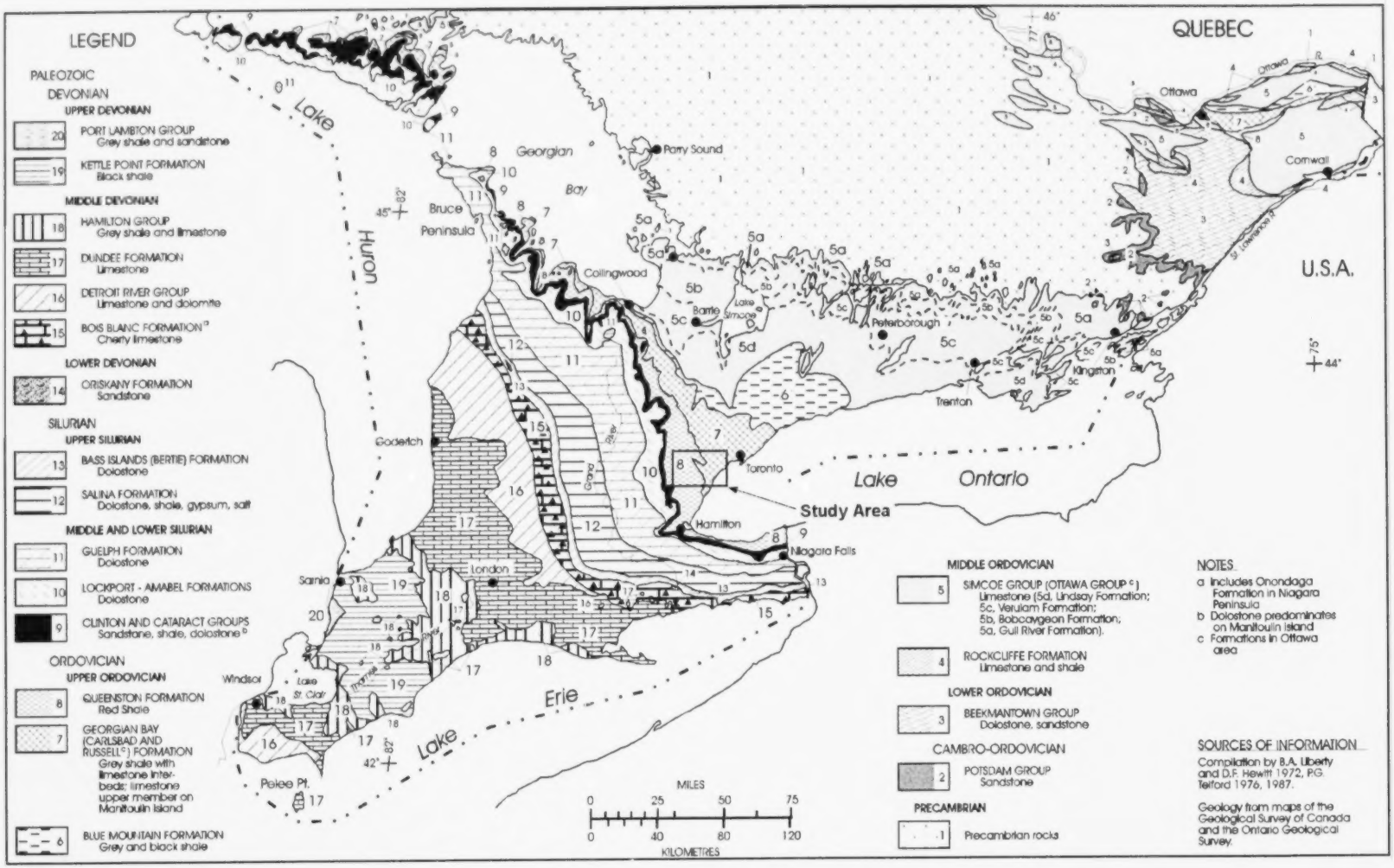

Figure 3. Bedrock geology of southern Ontario, showing formations referred to in the text.

Paleozoic Geology

Bedrock formations in the map area are of Ordovician and Silurian age (Figure 3), the latter being confined to the part of the study area west of the Niagara Escarpment. All formations have a shallow dip westward so that they are arranged shingle-fashion, with the oldest exposed in the east and the youngest in the west. The following description is based on field observation and previous publications by Caley (1940), Liberty (1969) and Telford, Bond and Liberty (1976).

ORDOVICIAN

Two shale formations of Late Ordovician age are mapped as underlying the area east of the Niagara Escarpment. The older is the Georgian Bay Formation, a dark grey to olive shale with numerous thin, fossiliferous, hard layers of limestone and siltstone. This formation has an estimated thickness of about 175 m. Its basal contact is located east of the study area and its upper contact extends from Clarkson to Bramalea, just east of the centre of the area. The Georgian Bay Formation is well exposed in outcrop as cliffs along the valleys of the Humber River, Mimico Creek, Etobicoke Creek and lower Credit River; it formed shorecliffs in glacial Lake Iroquois near Cooksville. It also crops out extensively on the floor of Lake Ontario offshore from Mimico (Lewis and Sly 1971). The contact with the overlying Queenston Formation is seldom exposed but can be seen along creeks south of Brampton. A prominent re-entrant in the contact is created by a buried valley near the present Credit River in the vicinity of Meadowvale. A lesser re-entrant is present northeast of Brampton under the Brampton esker; its location is documented by water-well data (Karrow, Harrison and Saunderson 1977).

The youngest Ordovician unit in the map area is the Queenston Formation, which underlies a broad belt in the west half of the area. It consists of red mudstone with siltstone interbeds; a few thin limestone beds occur near the base. Green deoxidized bands occur along siltstone beds and joints as well as in irregular blotches. The formation is nearly barren of fossils and has a thickness of about 140 m. The upper contact of the Queenston Formation is the local top of the Ordovician succession. It is disconformably overlain by the Silurian Whirlpool Formation along the base of the Niagara Escarpment from Milton to Cheltenham. The Queenston Formation is exposed in cliffs and slopes along the upper Credit River valley from Cheltenham to Huttonville; along the Sixteen Mile Creek valley (Photo 2); and at numerous other sites along stream valleys. Red till with abundant clasts of Queenston Formation shale near the corner of Eglinton and Mavis (west of Highway 10) indicates the presence of a previously unmapped outlier of Queenston Formation in that vicinity. Eroded slopes in the formation tend to badland development on a small scale. Examples of this are found near Cheltenham, Terra Cotta, Georgetown and Milton.

Photo 2. Queenston Formation outcrop in the west bank of Sixteen Mile Creek, south edge of map area.

SILURIAN

A sequence of several thin rock units, included in the clastic Silurian Cataract Group, makes up the rock succession in the lower part of the Niagara Escarpment. The formations are, in ascending order, the Whirlpool (4 m of grey to brown fine sandstone); Manitoulin (6 m of shaly grey dolostone); and Cabot Head—including Grimsby and Thorold equivalents—(18 m of green over red interbedded fossiliferous shale, siltstone and limestone). The escarpment cap rock includes the Reynales Formation (3 m of shaly brown to grey fossiliferous dolostone) and the Amabel Formation—including basal Irondequoit equivalent—(more than 30 m of grey fossiliferous dolostone). The upper contact of the Amabel Formation with the overlying Guelph Formation is to the west of the map area. The Amabel Formation is characterized by numerous reefal bodies, which contribute to its bedding irregularity and the knobby surface of the unit where exposed.

ECONOMIC GEOLOGY

Paleozoic formations have been and continue to be exploited as valuable mineral resources. The Georgian Bay Formation was formerly quarried at Mimico for ceramic products and at Cooksville for brick manufacture and heat-expanded lightweight aggregate (Hewitt 1969; Wilson 1980; OGS and Golder Associates Ltd., in press). The Queenston Formation is actively quarried at Cheltenham, Milton and Georgetown and was formerly quarried at Streetsville, Brampton and Terra Cotta, all for brick manufacture (Guillet 1967; Golder Associates Ltd. and Rowell 1996; OGS and Golder Associates Ltd., in press). Over large areas these formations are at or near the surface, but urban construction has generally covered areas suitable for quarrying the Georgian Bay Formation in Mississauga. The Queenston Formation remains accessible near Brampton, Georgetown, Milton, Terra Cotta and Cheltenham. Reports by Guillet (1967, 1977), Hewitt (1969),

Armstrong (2001) and Armstrong and Sergerie (2002) provide more detail on these resources.

The Whirlpool Formation has long been quarried as a building stone and ornamental stone. Former quarries are located near Kelso, Speyside, Silver Creek, Terra Cotta and Cheltenham, while quarrying is active near Limehouse and intermittently active near Cheltenham (Golder Associates Ltd. and Rowell 1996; OGS and Golder Associates Ltd., in press).

Easy access to the Amabel Formation along the exposed edge of the Niagara Escarpment provides the basis for presently active quarries on the escarpment west of Limehouse, and west and northwest of Milton (Golder Associates Ltd. and Rowell 1996). These quarries produce crushed stone, mainly for the western Greater Toronto Area market. Abandoned quarries are present at Milton and north of Limehouse. Further details can be found in reports by Hewitt (1969), Hewitt and Vos (1972), and Derry Michener Booth and Wahl and OGS (1989).

There has been limited interest in oil and gas in the rocks of the area. Two small gas pools exist in this area: the Hornby Gas Field, located to the northwest of Meadowvale West; and a past-producing gas pool—the Acton Gas Field—south of Limehouse (Sanford 1961; Carter, Ostrowski and Spears 2001).

STRUCTURAL DISTURBANCE

Although the Paleozoic formations of the area are nearly flat lying and reveal little evidence of later structural disturbance, manifestations of near-surface stress-release were encountered at several places in Mississauga. These form a northward continuation of features described in the Hamilton area (White, Karrow and Macdonald 1973; Karrow 1987b). The features can be classed in two separate groups. The first group is surface lineaments seen almost exclusively on early airphotos in areas of outcrop of Queenston and Georgian Bay formations. Nearly all of these occurrences, numbering about a dozen, are now destroyed or concealed by urban construction and unavailable for further investigation. Their locations are shown on Map 2223 (back pocket). L.J. Chapman (personal communication, 1988) noted a fold in shale at the former Ontario Research Foundation parking lot at Sheridan Park in Mississauga; this is on the trend of a surface lineament. The internal structure of the lineament indicates the feature is a "pop up". One lineament was still undisturbed in 1987 and was visible on the ground as a low ridge trending

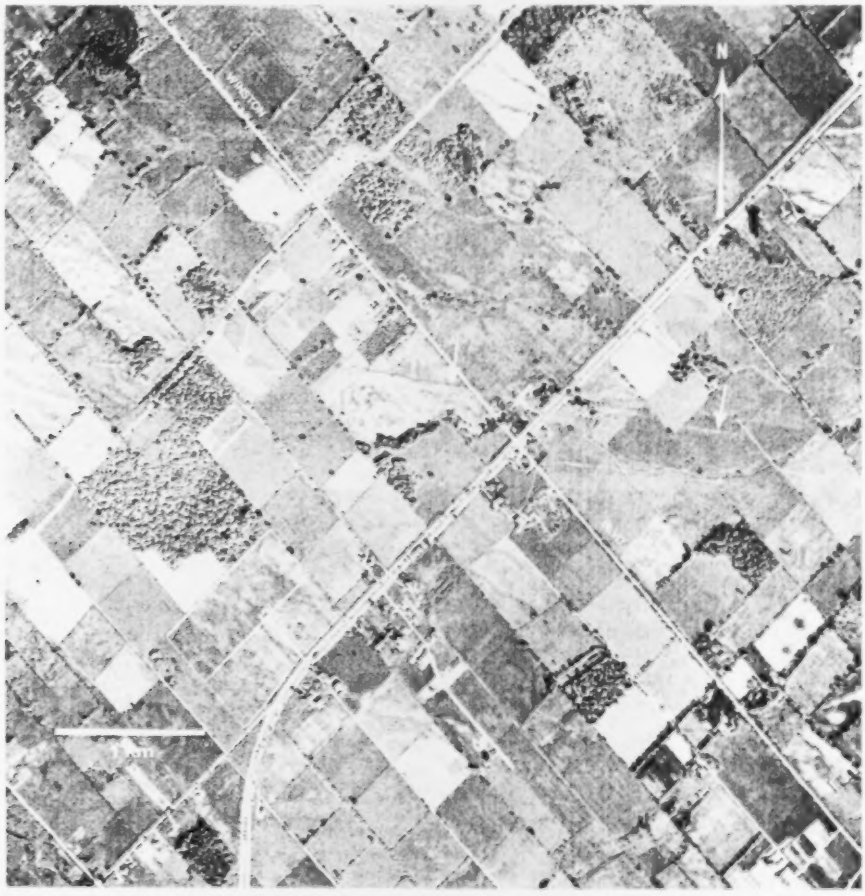

Photo 3. Airphoto of pop-up linear ridge (arrows) trending east near the intersection of Winston Churchill Boulevard and the Queen Elizabeth Way (QEW) (airphoto number MNR 54-4323,25-198).

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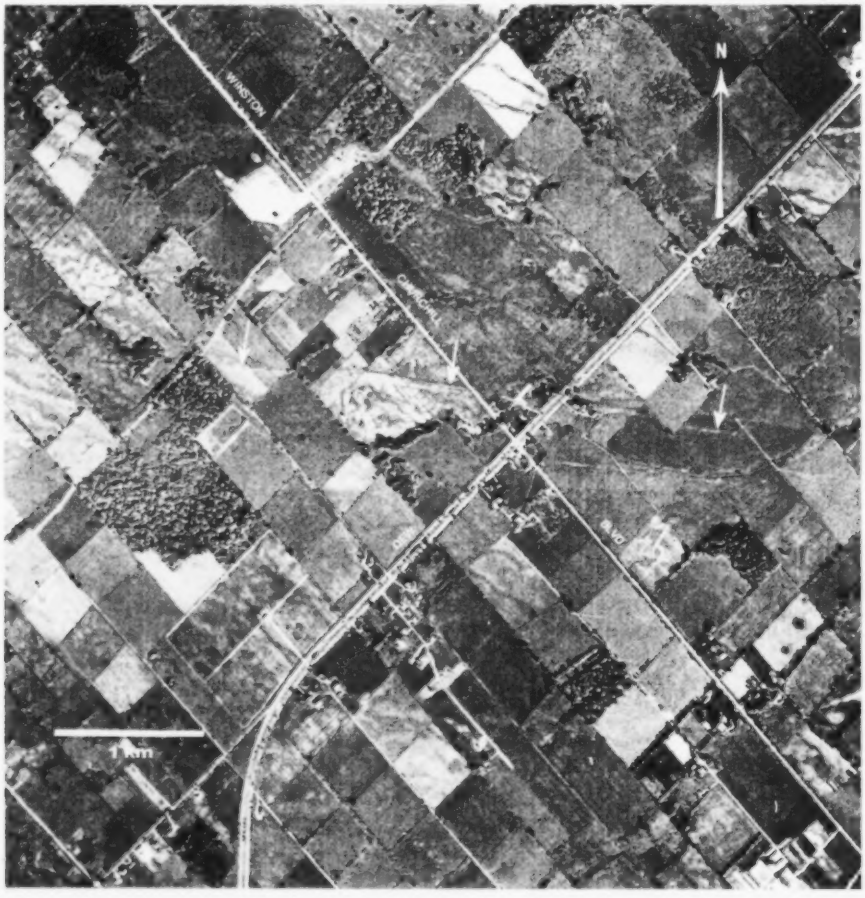

Photo 3. Airphoto of pop-up linear ridge (arrows) trending east near the intersection of Winston Churchill Boulevard and the Queen Elizabeth Way (QEW) (airphoto number MNR 54-4323.25-198).

east across a field and through the intersection of Winston Churchill Boulevard and the QEW (Photo 3). It has since been destroyed by industrial development. The similarity of these features to those observed on airphotos, on the ground, and in excavated sections in the Hamilton area indicates a similar origin as "pop ups" or stress-release features. Although lineaments or ridges in the Brampton map area trend predominantly east, a northerly or oblique direction is also present. They occur unmodified both above and below the glacial Lake Iroquois shoreline, suggesting they are postglacial in age.

The other group of such features includes small folds seen in section, but with no surface expression visible on airphotos or the ground. These are known from 3 sites. One occurs in the west bank of Spring Creek (a tributary of Etobicoke Creek) southeast of the intersection of Derry Road East and Dixie Road (west of Pearson International Airport). At this site a low, asymmetrical fold is present in Georgian Bay Formation shale under about 3 m of till (Photo 4). A second occurrence was found in an excavation for the south abutment of a bridge carrying Kennedy Road over Highway 401 (southeast of Brampton). At this site a small fold is present in Queenston Formation shale. Lastly, two small folds were noted high in the southeast and southwest walls of the quarry of the former Cooksville Brick Company in Georgian Bay Formation (Photo 5).

There is a reference with a photo (Parks 1913, p.18), in *Guide Book* 5 of the 1913 International Geological Congress, to a small fold in the rock near Streetsville:

"A cliff of about 25 feet (7.6 m) of limestone and shale is presented by the scarped bank of the river near the bridge to the northward of Streetsville Junction. The lower portion only is actually exposed and shows the heavy bryozoan layer of about two feet in thickness. Beneath this are thin-bedded limestones and shales, which may belong to the Richmond or to the underlying Lorraine...

Just below this point an interesting minor anticline is shown: the heavy bryozoan layer forms the surface rock, but is covered by three feet of boulder clay containing pebbles and also corals and stromatoporoids of the local formation. The northeast side shows glacial grooving and polishing, but the southwest side is much less affected by the passage of the glacier."

Airphotos taken in 1954 show a low, north-trending ridge on the low terrace of the Credit River north of Britannia Road West, which could be a pop up or a river-formed bar. Airphotos taken in 1971 show the ridge as largely gone or obscured. A visit to the site in the summer of 1991 was inconclusive. Vegetation and erosion-control works have eliminated exposures in the area. Reconstruction of the Britannia Road bridge, underway in 1991, resulted in excavations that suggest the river bed is essentially on bedrock. Based on the 1913 photo and description, this feature is presumed to be another pop up.

The origin of these features has been discussed by White, Karrow and Macdonald (1973), White and Russell (1982), and in a review of neotectonics in Ontario by Karrow and White (2002). They are believed to be caused by high *in situ* stresses in the rock, which have caused near-surface failure or buckling of the strata. The occurrence of these features only near the surface is believed to be due to the lesser confining pressures in such settings. Confining pressure increases so rapidly with depth that such failures are apparently only possible near the surface. However, tunnelling and excavation, including quarrying, can precipitate them. Similar features in Ohio and Kentucky, known there as "stream anticlines", are found in stream beds where erosion of overlying cover has allowed the pressure-release structures to form (Swinford 1985). Fractures in bottom sediments on the floor of Lake Ontario have a similar orientation and appear related to recent earthquakes (Thomas et al. 1993). The postglacial origin of at least some of these features has been documented elsewhere (Johnson 1916; Finamore and Baje 1983; Karrow 1987a) and indeed some have been observed to happen in recent time (Simmons 1966; Karrow 1987a). There would appear to be some risk of structural damage to buildings in the vicinity of pressure-release structures.

Photo 4. Small anticline in Georgian Bay Formation along Spring Creek, west of Pearson International Airport.

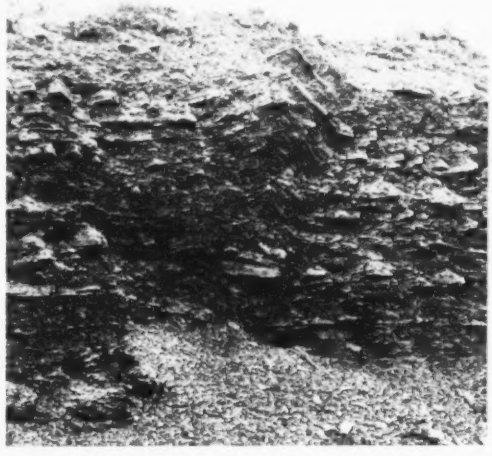

Photo 5. Small fold (pop up) in Georgian Bay Formation, quarry of the former Cooksville Brick Company.

Quaternary Geology

GEOMORPHOLOGY

In this part of the report, landforms are described in more detail and their origins are discussed. They are dealt with in their historical order, from oldest to youngest, as presently understood.

Bedrock Topography

The form of the bedrock surface is of considerable interest because it is a boundary between underlying rock and overlying soil (in the engineering sense), and thus marks a major change in material properties. In construction or other civil engineering works, equipment required for excavation may be very different for the two classes of material, and rock often requires blasting, resulting in very different costs for excavation. The bedrock surface also forms a marked change in water permeability and is thus of importance in water resource studies and planning for waste disposal sites. In this connection, linear bedrock surface depressions, referred to as buried valleys (see discussion below), often contain ancient stream sediments that may form important aquifers. Bedrock topography and drift thickness are also of commercial interest for mineral exploitation of bedrock formations for quarrying (e.g., crushed stone and ceramic products).

The topography of the bedrock surface is the result of the interaction of bedrock lithology and structure, rock weathering, and erosional forces of streams, glaciers and lakes in preglacial, interglacial, glacial and postglacial time. The present rock surface thus varies greatly as to time of development, and its history is complex. Over much of the study area drift is relatively thin, but even so, our knowledge of the shape of the bedrock surface remains quite imperfect.

BEDROCK SCARPS

The Niagara Escarpment forms the major bedrock and topographic feature in the area and has previously been described in general terms (*see* "Physiographic Classification"). It separates the large expanse of shale lowland, which forms the bedrock over most of the study area, from the dolostone upland along the west edge of the map area. The Niagara Escarpment originated through differential weathering and stream erosion of easily weathered and eroded thick shale formations that underlie more massive and resistant dolostone cap rock. The escarpment is represented in the map area by a vertical dolostone cliff, which is most prominent in the south near Milton. The cliff lessens in height and prominence northward to Limehouse, only to become more evident again north of there. Below the cliff, steep slopes give way to more gentle slopes that grade eastward to a dissected shale plain, commonly covered by glacial deposits.

A subdued bench—the secondary "Whirlpool Escarpment"—near the main body of the Niagara Escarpment is formed by Whirlpool Formation sandstone. The bench is narrow and locally present north of Highway 401. It adopts a northerly trend north of former Highway 25, diverging from the main body of the Niagara Escarpment, which trends north-northwest from there toward Acton. The bench is most evident on topographic maps as a series of ravine heads where rapids and small waterfalls mark the passage of streams over the sandstone before their rapid descent down valleys incised into the red Queenston Formation shale. This bench also can be seen on the east side of the Terra Cotta outlier and north to Cheltenham, east of the main body of the Niagara Escarpment.

Another subdued scarp-like feature—the "Queenston Escarpment"—is found near the contact of red Queenston Formation shale and grey Georgian Bay Formation shale. Urbanization has helped conceal its form but it is evident as a steeper slope trending from the south edge of the study area in a northerly direction toward Pearson International Airport. It may continue eastward into Etobicoke and northward up the Humber River valley. In the south, shale is at or near the surface and, between Erindale and Cooksville, shore erosion by glacial Lake Iroquois formed a shale cliff. The reason this steepened shale slope formed is unknown but could be partly influenced by a concentration of carbonate beds known to occur (Caley 1940) in the lowermost part of the Queenston Formation. An upward increase in clastic and carbonate hard bands in the Georgian Bay Formation (Telford, Bond and Liberty 1976) may also contribute to greater erosional resistance in this zone.

BURIED VALLEYS

The Ordovician shale surface slopes southeastward from the Niagara Escarpment to the Lake Ontario shoreline and eastward toward the Humber River valley. Its gentle relief is interrupted by several buried valleys. The most prominent of these is the "Meadowvale Valley", which represents an ancestral course of the Credit River and extends from Georgetown to Meadowvale. It has a depth of at least 60 m. The broadened flare of the inset Credit River valley is influenced by the incompletely buried valley from Norval to Meadowvale. The buried valley's course downstream from Meadowvale is uncertain as it fades out toward the "Queenston Escarpment". A weakly defined bedrock low trending along the present Credit River valley, through Erindale, may be related.

Near Georgetown, several buried valleys appear to join and relationships remain poorly understood. There is a northerly trend of buried valleys near the base of the Niagara Escarpment. This trend is followed by the Credit River between Cheltenham and Georgetown; by Sixteen Mile Creek south of Stewarttown to Kelso; and by the valley west of the Milton outlier. Silver Creek isolates the Terra Cotta outlier along a parallel course. This northerly trend of the valleys more or less parallels the Niagara

Escarpment and the former trend of the retreating (or advancing) margin of the Ontario ice lobe (Figure 4). It would seem likely that repeated episodes of ice-marginal drainage along the topographically influenced ice margin may have been the principle cause of valley cutting. These valleys are commonly about 30 m in depth.

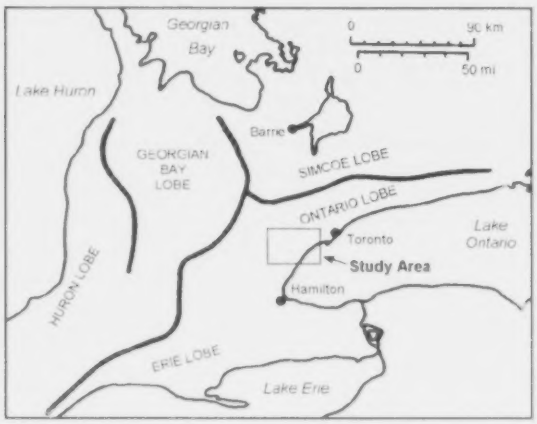

Figure 4. Areas of influence of major glacial lobes in the vicinity of the study area (*from* Karrow, Jopling and Martini 1982).

Lesser bedrock valleys on the shale plain, and their corresponding present streams, have been noted southeast from Milton (West Sixteen Mile Creek); southeast from Hornby (Sixteen Mile Creek); from Snelgrove to Long Branch (Etobicoke Creek); from Malton to Islington (Mimico Creek); and from Thistletown to Weston (Humber River). These valleys are usually 10 to 30 m deep.

ESCARPMENT RE-ENTRANT VALLEYS

West of the Niagara Escarpment, the bedrock surface is very rough and irregular in detail. A north-trending linearity to surface forms can be attributed to a combination of reefal rock ridges and ice-marginal meltwater erosion. Areas stripped for quarrying at the Dufferin Aggregates quarry, north of Kelso, revealed up to 15 m of relief with small gorges, falls, rapids, and potholes up to 3 m in diameter (Photos 6 and 7). These features have since been removed by quarrying.

Throughout its length in Ontario, the Niagara Escarpment is marked by prominent erosional notches at varying intervals; two of these are partly within the Brampton map area. The relative importance of stream and glacial erosion in their formation has long been debated. For example, Straw (1968) felt ice streams dominated. Regional studies of bedrock topography (Karrow 1973) suggest some relationship to bedrock valleys and this author feels that some combination of stream and ice erosion created their present form.

The re-entrant west of Milton (the Campbellville re-entrant) forms a convenient ramp up the Niagara Escarpment for the Canadian Pacific Railway and Highway 401. Along its north edge 2 gorges, each about 1 km long, notch the escarpment and are included in the Hilton Falls Conservation Area. Small underfit streams form waterfalls at their heads and they appear to be related to shallow rock valleys having an ice-marginal (northerly) trend. The author interprets their origin as having been eroded, perhaps catastrophically, by glacial meltwaters.

The second, and smaller, re-entrant (the Acton re-entrant) is located west of Georgetown and Limehouse and has been studied by Easton (1988), who traced a narrow buried bedrock valley from it to Limehouse. Its eastward continuation and relationships to the several buried valleys near Georgetown remain uncertain. The Acton re-entrant also aids transportation by providing the route over the Niagara Escarpment for the Canadian National Railway and its affiliate, the Goderich–Exeter Railway.

TOPOGRAPHY AND ITS INFLUENCE ON THE DISTRIBUTION OF BEDROCK FORMATIONS

The shape of the bedrock surface has an obvious influence on the mapped distribution of the various bedrock formations. Karrow (1973) has commented on the limited attention generally paid to bedrock topography in depicting contacts on bedrock geology maps; further support for the

Photo 6. Irregular surface of Amabel Formation at Dufferin Aggregates quarry with small gorges, waterfalls and potholes.

Photo 7. Pothole eroded in Amabel Formation by glacial meltwater, Dufferin Aggregates quarry.

concern was encountered in the mapping of the Brampton area. In addition

- the presence of subcrops of Queenston Formation shale in the Acton re-entrant was commented on by Karrow (1968, 1973);
- greater irregularity in the Queenston–Georgian Bay formations contact near Brampton because of the buried valley under the Brampton esker has been noted by Karrow, Harrison and Saunderson (1977);
- an outlier of Queenston Formation is inferred to be present northwest of Burnhamthorpe Road and Highway 10; bedrock elevations are higher there and till in the vicinity has a deep red colour.

The highly contrasting colour of red Queenston Formation and grey Georgian Bay Formation shales facilitates the location of the contact from well records, and further refinement should be possible when bedrock topography is fully taken into account when revising the location of bedrock contacts (e.g., Karrow 1970). Other areas of high relief in the bedrock surface are known along the Humber River valley (Watt 1957, 1968) but remain ill-defined and their relationship to bedrock formation contacts uncertain.

Palimpsest Topography

Palimpsest topography is a landscape that "inherited" its surface form from previous, now underlying, surface landforms. Aside from bedrock features that influence the present topography, earlier-formed Quaternary deposits can also affect the present topography.

One striking example of such features in the study area is the Brampton esker (*see* Map 2223), which stratigraphic evidence shows to have originated before the last (Halton) ice advance, possibly during the previous (Newmarket) ice retreat (Karrow, Harrison and Saunderson 1977). The esker, which forms a northwest-trending ridge at the present surface about 7 km long, 0.2 to 0.6 km wide, and about 15 m high, has a till cover about 1 to 3 m thick. Several kettle holes, one of which is occupied by Heart Lake near the esker's northwest end, occur along its length. Some of these kettle holes are 10 to 15 m deep, which is much greater than the till cap and of a similar size to the height of the ridge. These relationships suggest that the ice blocks that formed the kettle holes were enclosed in the esker sediments during stagnation and ablation associated with the previous (Newmarket) ice retreat. The intervening Halton advance deposited a veneer of till over the esker and its contained ice blocks. Melting of the ice blocks and formation of the kettle holes at the present surface followed the Halton ice retreat. Masses of foundered Halton Till should thus be found at the base of the kettle holes, but this has not been proven by bore holes into the kettles. Similar relationships and history have been suggested for Spongy Lake, near Kitchener (Karrow 1993). Northwest of Georgetown, and west of Glen Williams, gravel pits reveal a similar stratigraphy to that of the Brampton esker; that is, Halton Till over glaciofluvial sand and gravel. There also, a few small kettles extend much deeper than the till covering the gravels and suggest ice block entrapment during the previous ice retreat.

The till plain of gentle relief flanking the Credit River valley northwest of Georgetown, at least in part, appears to be a palimpsest surface. This surface formed as an outwash plain that was overridden and little disturbed by the Halton advance. Similar sequences of Halton Till over outwash gravels were noted in the Hamilton area south of the Milton outlier (Karrow 1987a, p.47).

Other examples of palimpsest topography have been noted in various parts of the study area. Irregular surface topography in the Halton Till plain (see description below) between Hornby and Speyside is associated with inliers of glaciofluvial sand appearing through the till. The form of the underlying deposits remains uncertain, but they add relief to the till plain in that area.

No doubt other elements of palimpsest topography remain unrecognized; more subsurface data are needed to aid in better understanding of the relationship between buried surfaces and the present surface.

Till Plains

To the casual observer, most of the Brampton area appears to be a rather simple till plain of low relief. In fact, much of the relief is a reflection of underlying topography, mainly bedrock, but also of older Quaternary deposits. The surface has been modified to varying degrees in postglacial environments, particularly glaciolacustrine, and subsequently by stream erosion.

WENTWORTH TILL PLAIN

The oldest till plain is that formed of Wentworth Till. It is restricted to an area of less than 5 km^2 in the northwest corner of the map area (*see* Map 2223) and exhibits undulating to hummocky topography. Just beyond the western edge of the study area, the till plain becomes drumlinized in a narrow zone immediately behind the Paris moraine. This moraine trends northeast and marks the limit of the Wentworth advance (Karrow 1987a).

HALTON TILL PLAIN

The largest till plain in the map area is the Halton Till plain, formed by the last major advance of the Lake Ontario basin ice lobe. West of the Niagara Escarpment, only small patches of Halton Till plain have been delineated in the current study area. Probably part of the area mapped as bedrock complex consists of till plain. However, the roughness of the bedrock surface, and the abundance of local dolostone boulders, many of large size, make separation of till, ablation gravels and true bedrock outcrop impractical at the present scale of mapping.

The major area of Halton Till plain is east of the Niagara Escarpment. Over large areas it has been modified by sedimentation in glacial Lake Peel, the main effect of which was to further subdue the gentle topography by the partial filling of depressions with silt and clay. Otherwise, the surface is gently undulating (Photo 8), grading into

streamlined forms such as flutings and a few drumlins, such as those seen near Ashgrove (*see* "Drumlins and Flutings"). Much of the Halton Till plain is now concealed by urban development in the vicinity of Etobicoke and North York.

Where relatively undisturbed and moisture conditions are optimal, the undulating till surface displays a mottled pattern on airphotos. This pattern is generally more prominent in moraines, but is widespread elsewhere as well. Commonly these patterns are random, but locally there are linear arrangements suggestive of some relationship to ice flow direction and the trend of the ice margin. Watt (1957) speculated that sloughing of supraglacial debris into glacial lake waters may have caused the patterns. Careful excavation and detailed examination should be carried out to further clarify their origin. Airphotos illustrating the patterns have appeared in reports by Watt (1957, p.23) and Karrow (1987a, p.17).

Drumlins and Flutings

Drumlins—elongate, streamlined hills generally formed of till—are rare in the Brampton area. Although common in adjacent map areas to the southwest and west (Karrow 1968, 1987a), where they are formed of sandy Wentworth Till and Port Stanley Till, few features recognizable as drumlins have been seen in the present map area. As already mentioned (*see* "Wentworth Till Plain"), several Wentworth Till drumlins lie just west of the northwest corner of the study area. Farther south, the area was mostly overridden by the Halton ice which, with few exceptions, did not form drumlins in this vicinity. The steep stoss end of one Wentworth Till drumlin lies just within the study area about 3.5 km southwest of Speyside (*see* Map 2223).

Streamlined drumlinoid hills intermingled with less well-defined forms occur near Ashgrove in an area where there is evidence of overridden sand. Only 3 such features have been identified, unlike typical drumlins, which are usually found in large groupings known as drumlin fields. A single feature designated as a drumlin was also identified in southwestern Brampton. The long axes of these drumlinoid features conform to other evidence (striae, flutings) indicating ice movement to the west or northwest out of the Lake Ontario basin.

Flutings are shallow grooves in the till surface formed by flowing ice. They are readily apparent on airphotos but commonly too subdued to see on the ground. Scattered occurrences have been noted on the Halton Till plain between Milton and Streetsville. It is evident that modification by glaciolacustrine sedimentation has tended to mask their presence, as noted by Karrow (1987a) in the Hamilton area to the south. Much more prominent flutings, some of which can readily be seen on the ground west and south of Streetsville (Photo 9), are common southeast of the Trafalgar moraine, where there is little evidence of later modification by lake action. Near Streetsville there is an obvious fanning arrangement of the flutings as if to reflect a local projection of the ice front up the Credit River valley. Flutings have a marked control on the orientation of small streams.

Photo 8. Gently undulating Halton Till plain northeast of Georgetown.

Moraines

Moraines are linear undulating to hummocky tracts or single to multiple ridges, commonly formed of till, that accumulated when the rate of forward ice flow was roughly in balance with the rate of melting of the ice margin. Moraines are important in delineating former ice margins and in indicating the general direction of ice movement. Several moraines have been identified in the Brampton map area; they vary in size from small to moderate.

The oldest such feature is a small hummocky and bouldery ridge of Wentworth Till in the northwest corner of the area (*see* Map 2223). It is a little younger than the Paris moraine (Figure 5), located west of the study area, but is considered to be of little significance because of its small size. In size, position and trend it resembles the Moffat moraine (*see* Figure 5) of the Guelph and Cambridge areas (Karrow 1968, 1987a) and may be roughly correlative.

All other moraines in the study area are believed to have been formed in association with the Halton advance. There is no clear evidence of any significant readvance associated with the various Halton moraines. The moraines

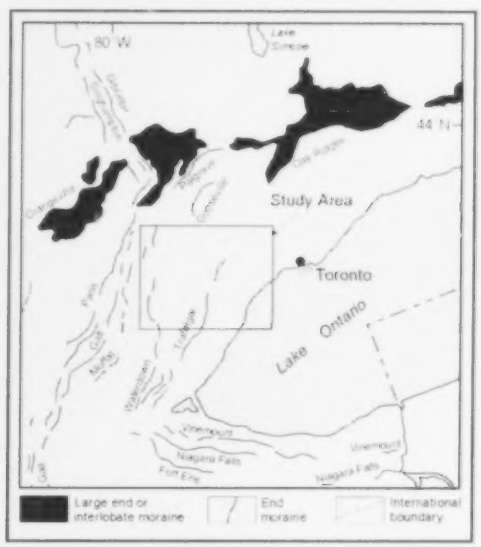

Figure 5. Location of major moraines in the vicinity of the study area (*adapted from* Barnett 1992).

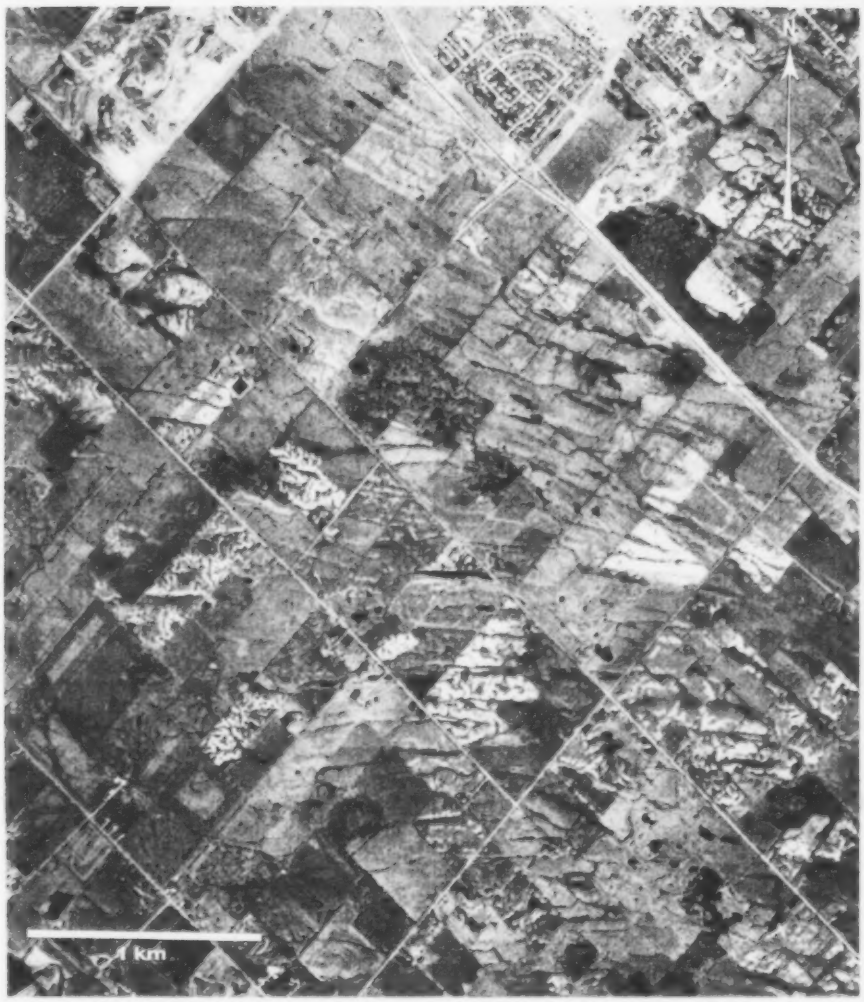

Photo 9. Airphoto showing mottled Trafalgar moraine and flutings in till plain south of Streetsville (airphoto number NAPL A23665-220).

are considered to be recessional features formed during the spasmodic retreat of the Halton ice.

ACTON MORAINE

The oldest and westernmost is a hummocky ridge of ice-contact (kame) gravel named by Straw (1968) the Acton moraine. North of former Highway 7 it has a steep ice-contact face on its east side (*see* Map 2223). Although considered by Chapman and Putnam (1984) to be an extension of the Galt moraine (*see* Figure 5), Straw noted the diminishing size of the Galt moraine toward Acton and interpreted the Acton moraine as representing a later cross-cutting advance correlative with the westernmost Waterdown moraines of the Hamilton area (Karrow 1963). This author agrees with Straw's interpretation and feels that the Acton moraine represents the westernmost position of the Halton advance. The bush-covered bedrock complex south of the Acton re-entrant makes southward tracing of a continuation difficult.

In the zone between Acton and Milton, there is only a short ridge fragment of till with an east-facing ice-contact face about 2 km southwest of Limehouse (*see* Map 2223). The reason for the abundance of coarse sediment associated with the Halton margin north of Limehouse, in contrast to its usual subdued morainic topography, may be that the ice encountered an abundance of such debris in the Credit River valley nearby to the east. Halton Till is known to overlie thick meltwater deposits along the Credit River valley north of Georgetown.

Another younger Halton moraine is a ridge along the crest of the Terra Cotta outlier (*see* Map 2223), which continues a short distance beyond its south end for a total length of less than 3 km. It more or less parallels the Acton moraine but is separated from it by about 3 km. It is not given a separate designation.

CHELTENHAM MORAINE

The Cheltenham moraine (Taylor 1913) extends some 4 km into the study area from the north just east of the

Credit River valley (*see* Map 2223). Its relationship to the Credit River valley suggests that the latter took its position as a path for ice-marginal drainage at about the time the moraine was formed. The moraine consists of a tract of hummocky till with only slight elevation above adjacent till plain. It is, however, clearly evident on airphotos. It could not be traced much south of Terra Cotta. Its position, and elevation about 70 m lower than the fragment on top of the Terra Cotta outlier, indicate a distinctly younger age for the Cheltenham moraine. White (1975) questioned the existence of the Cheltenham moraine and reclassified part of it as Palgrave moraine. The designation Cheltenham moraine is retained here for the portion in the Brampton map area. It is considered to be nearly equivalent to the Palgrave moraine (*see* Figure 5) in age.

KELSO MORAINE

The first assemblage of ice-marginal features with significant continuity across most of the area is given the provisional name of Kelso moraine. It is best defined as a marked till ridge arcing convexly westward into the Campbellville re-entrant, where it crosses Highway 401 just east of Kelso Lake (*see* Map 2223). It is traceable northward with one or two fragments of subsidiary ridges positioned to the east of the most traceable one. It continues near the base of the Niagara Escarpment to former Highway 25 and gradually trends east of north toward Georgetown with a meltwater channel and outwash sediments in front (west) of it. Across the Credit River valley beyond Georgetown the same trend is represented by a low till ridge fronted on the northwest by a broad linear depression partly filled by lake sediments. In this form it continues to the north edge of the map area, where it crosses Etobicoke Creek. Tributaries of Etobicoke Creek follow the frontal depression, and the path of the main stream has a prominent kink where it crosses the moraine trend. South of Kelso, the moraine is not distinguishable, as only a single ice-marginal feature has been recognized from Milton to Mount Nemo, beyond which several Waterdown moraines (*see* Figure 5) are well defined. The Kelso moraine probably corresponds to an intermediate member of that group. To the north, in the Bolton area, an approximate correspondence to the Gooseville moraine (White 1975) can be inferred, although White (1975) did not map the Gooseville moraine as extending to the south edge of the Bolton map area. If continuity can be demonstrated, the name Gooseville moraine would apply throughout on the basis of priority.

In 1963, new cuts along the Canadian National Railway line about 3 km southeast of Speyside and east of former Highway 25 crossed the trend of the Kelso moraine. Silty clay Halton Till overlay sand to the north and southeast of the ridge while in the ridge itself alternating layers of till and sand sloped up to the distal side of the ridge, suggesting a thrust-stacked structure.

TRAFALGAR MORAINE

The youngest of the Halton moraines in the study area is the Trafalgar moraine (Chapman and Putnam 1951). It is traceable from the Hamilton area to the south (Karrow 1987a), where it has its type locality, to the west edge of Streetsville, some 7.5 km within the Brampton map area (*see* Map 2223). The moraine is a belt of hummocky topography bounded on the southeast by fluted till plain (*see* Photo 9) and on the northwest by extensive thin lake sediments deposited on a lower and flatter terrain. The moraine continues as a hummocky (mottled on airphotos) belt about 7 km long extending from the east edge of Streetsville east of the Credit River toward Pearson International Airport. Extensive urban development and the poor quality of available older airphotos has frustrated attempts to trace it farther. Simple linear extrapolation would place it near the Thistletown area, where the main branches of the Humber River join. However, ridge patterns north of the airport are oriented northward, which would suggest a swing of the ice margin in that direction, a not unreasonable trend if the ice developed a projection up the Humber River valley.

As with the Cheltenham and Kelso moraines, the Trafalgar moraine also affects drainage patterns. Its position causes a major bend in East Sixteen Mile Creek, and a junction with the west branch just north of the moraine in the Hamilton map area. In the Brampton map area the moraine's location coincides with a kink in the Credit River at Streetsville; causes a right-angle bend in Fletchers Creek, which joins the Credit River just north of the moraine; and controls tributaries of Etobicoke Creek. Southeast of the moraine, minor drainage follows the till plain flutings. Efforts were made in the late 1990s by local conservationists to protect the moraine from development, following similar efforts in the Oak Ridges moraine north of Toronto.

Kames

Irregular masses of ice-contact sand and gravel (kames) are not common in the area. The greatest concentration of these is associated with the Acton moraine, which is actually a kame moraine. Other masses occur west and southwest of Georgetown and a few small mounds extend toward former Highway 25 along the Kelso moraine.

A belt extending from the Niagara Escarpment to former Highway 27 through Hornby, Streetsville, Britannia and Weston embraces scattered occurrences of kame sand or gravel (*see* Map 2223). In most cases these appear to originate from below the surface till but some may be true surface kames.

Eskers

As with kames, eskers are rare in the area. The most notable is the Brampton esker, already described as a palimpsest feature (*see* "Palimpsest Topography").

An irregular sand ridge parallel to ice flow direction and to the Credit River valley southwest of Huttonville

Photo 10. Airphoto showing distribution of ice-block depressions (kettles) along the Brampton esker, north of Brampton (airphoto number NAPL A23665-82).

(*see* Map 2223) extends for about 2 km and is believed to be a small esker; its surface was probably reworked by glacial lake waters.

Kettles

Kettles, or ice-block depressions, form by the burial and subsequent melting of stranded blocks of glacial ice. The most notable kettles in the area are along the Brampton esker (Photo 10). Their origin as long-lasting blocks that melted after the Halton retreat, has already been described (*see* "Palimpsest Topography"). Smaller kettles northwest of Georgetown have a similar origin, inasmuch as the kettles extend much deeper than the till cap over glaciofluvial gravels.

Although most depressions in moraines were probably constructed from the irregular heaping of material around them, at least some were formed as ice-block depressions. Other examples of kettles formed in this way can be seen in the Cheltenham moraine northeast of Terra Cotta.

Outwash Plains

Meltwater sediments deposited in nearly flat plains constitute outwash. In the Brampton area most such features are exhumed from pre-Halton or inter-Halton events; that is, they have been exposed by the erosional stripping off by stream action of the overlying Halton Till. As such, they represent buried topography re-exposed. Such deposits occur along the Credit River valley north of Georgetown.

Only comparatively small areas of outwash gravel plain are present: west of the Niagara Escarpment near former Highway 7; west of Stewarttown; and in the Campbellville re-entrant west of Milton. An outwash sand plain occurs west of the Kelso moraine south of Stewarttown (*see* Map 2223).

Meltwater Channels

There is evidence of a concentration of ice-marginal meltwater channels along, particularly above, but also below, the Niagara Escarpment. These erosional channels commonly scoured away the glacial deposits, leaving behind coarse boulder lags resting on dolostone bedrock. Meltwaters apparently flowed south along a succession of bifurcating and anastomosing channels. Such channels alternate with kame gravel ridges along the Acton moraine. South of the Acton re-entrant, they are not readily definable in the irregular topography of the bedrock outcrop complex. Chapman (1985) has postulated that overflow waters draining a glacial lake between the Simcoe and Ontario lobes in the vicinity of Uxbridge passed along the Niagara Escarpment from west of Cheltenham to Acton and southwest to glacial Lake Whittlesey (Figure 6) in the Erie basin.

A small but striking ice-marginal meltwater channel is present on the west side of the Kelso moraine where crossed by Highway 401. The Kelso dam impounds Kelso Lake, which floods part of this channel. A meltwater channel also fronts the moraine north of former Highway 25.

The general lack of outwash and meltwater channels can be attributed to the fact that as the Halton ice retreated downslope into the Lake Ontario basin, it was commonly fronted by glacial lakes and the nature of the glacial debris, which included reworked glaciolacustine sediments, did not yield large quantities of coarse glaciofluvial sediment.

Lake Plains

Gently undulating to nearly flat plains underlain by glaciolacustrine sediments constitute lake plain. Much of the area east of the Niagara Escarpment qualifies as lake plain to some degree, but lake sediments are often thin, discontinuous and of irregular distribution. The till is often at the surface or so thinly covered by lake sediment that the topography is essentially that of the till. There is a complete gradation from bare till plain to definite lake plain; boundaries are irregular and commonly difficult to define.

Lake plain associated with glacial Lake Peel (*see* Figure 6) occurs northwest of the Trafalgar moraine and east of the lower slopes of the escarpment (*see* Map 2223). Deeper lake silt and clay deposits tend to be concentrated in belts or areas near present drainageways. It is evident that glaciolacustrine deposits concentrate in lower areas on the till plain, which in turn show some correspondence to bedrock valley trends. Thus bedrock lows "show through" as lows in the till plain, which acted as glaciolacustrine sediment traps, and in turn being not entirely filled, tended to be lows in which postglacial drainage became concentrated. The result is the occurrence of deeper lake sediments in residual lenses near present valleys. These relationships are particularly evident near Milton, Hornby, Drumquin, Churchville, Malton and Thistletown.

The other major lake plain is that of glacial Lake Iroquois (*see* Figure 6), which followed glacial Lake Peel as the major glacial lake of the Lake Ontario basin. The

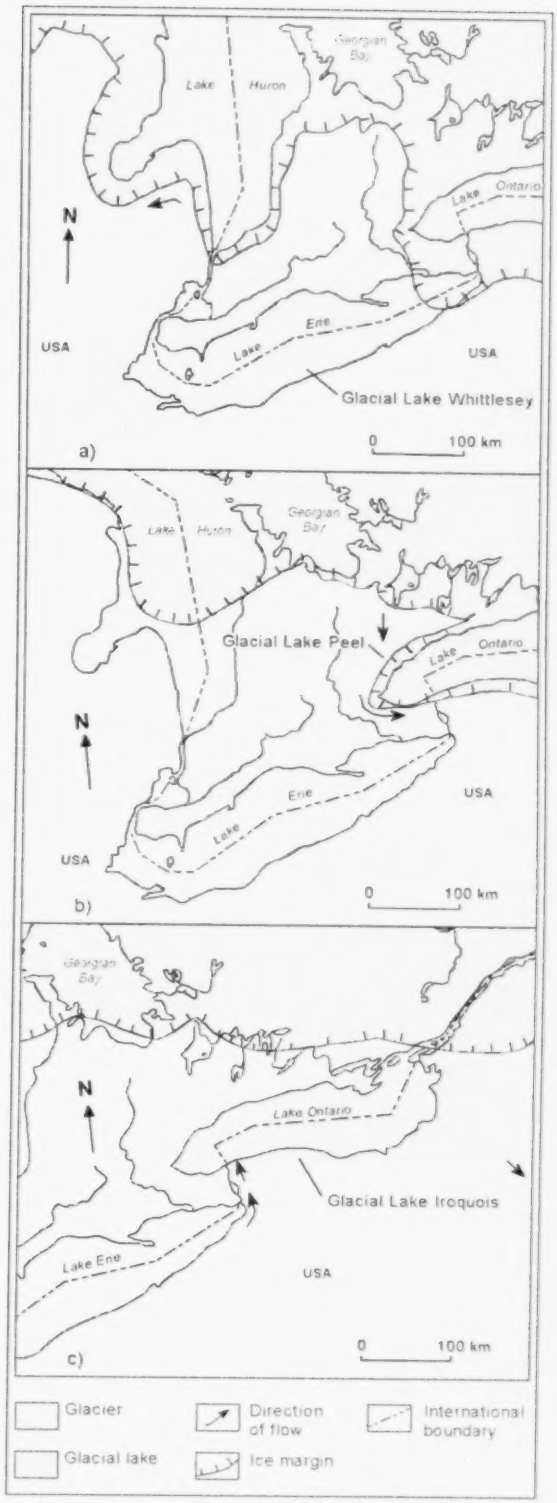

Figure 6. Locations of glacial lakes mentioned in the text: a) glacial Lake Whittlesey, 13 000 years BP; b) glacial Lake Peel, approximately 12 500 years BP; c) glacial Lake Iroquois, approximately 12 300 years BP. *Modified from* Barnett 1992.

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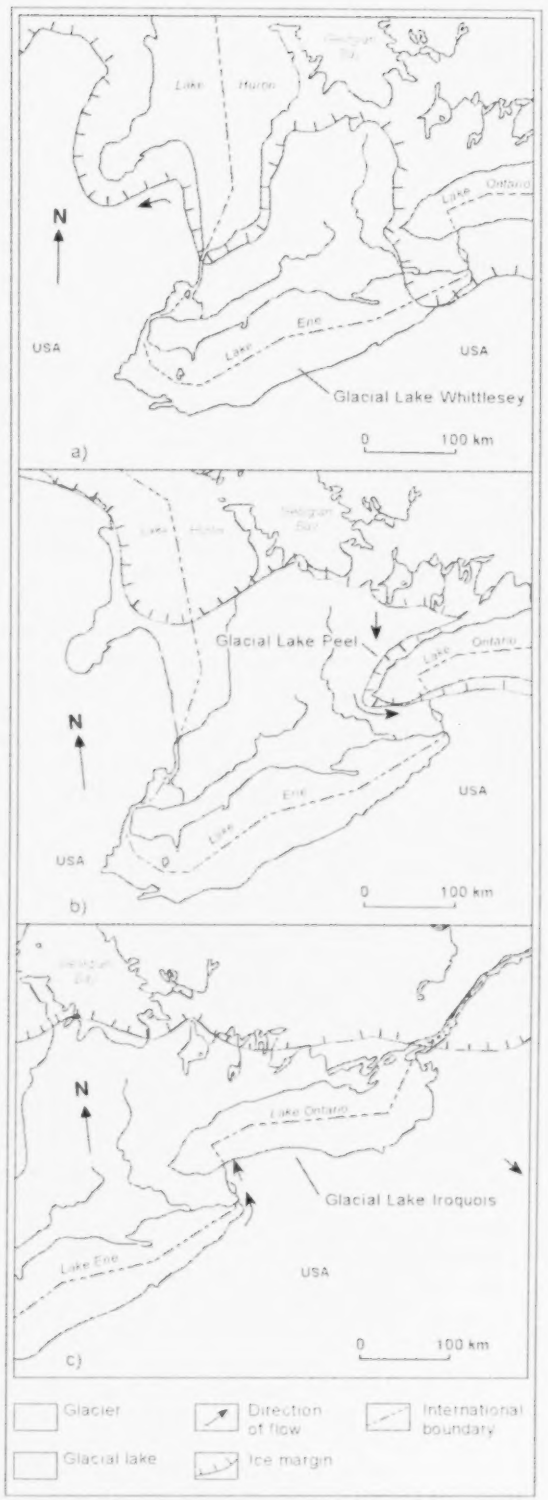

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lake plain occupies a belt inland from the shore of Lake Ontario, from the south edge of the map area north beyond Weston up the Humber River valley (*see* Map 2223). The glacial Lake Iroquois plain can be characterized as sand plain, underlain by nearshore shallow-water fine sand, which has been particularly dissected and gullied by post-glacial erosion southwest of Port Credit. Only small areas near the present Lake Ontario shore east of Port Credit and at New Toronto reveal the presence of deeper-water silt and clay. Exposures along the shore in these areas are commonly obscured by erosion protective works. The Iroquois plain slopes down from the Iroquois shoreline, at about 119 to 128 m, to the Lake Ontario shore at 75 m.

Abandoned Shorelines

Only 2 abandoned shorelines have been recognized in the area. These are attributable to one of the lower levels of glacial Lake Peel and to glacial Lake Iroquois. Shore features of glacial Lake Peel are rarely recognizable and knowledge of its levels is thereby limited. All the pre-Iroquois levels are grouped as glacial Lake Peel. Apparently, glacial Lake Peel water levels were only stable for brief periods and the water was shallow over large areas, so wave action was weak.

What is believed to be a glacial Lake Peel sand bar forms an arcuate ridge extending about 6 km southeast of Agerton (*see* Map 2223). A secondary feature about 2 km long parallels it across the Sixteen Mile Creek valley. These bars, with an elevation of about 189 m, formed at the margins of a local body of water northwest of the Trafalgar moraine. They extend southeast from a deltaic sand plain to which they are genetically related. The longer bar enclosed a lagoon on its northeast side. The bar sand was later subjected to wind action, which developed an undulating topography of minor dunes.

In contrast, the shoreline of glacial Lake Iroquois is generally prominent and clearly recognizable through most of its length in the area. Instrumental surveys of its elevations, including several sites within this map area (from the south edge to Etobicoke Creek), were carried out by Wilkinson (1959) following its general description by Coleman (1937a). The shoreline is present at the south edge of the map area as a shorecliff cut in shale bedrock west of Clarkson (*see* Map 2223). Small gravel bars front the cliff where it crosses Sheridan Creek and the rock cliff continues to the QEW where it swings northwestward into the mouth of the Credit River valley. A small embayment of glacial Lake Iroquois extended up the valley as far as the present-day campus of Erindale College. The embayment was closed off from the open lake by a large gravel bar about 2 km long, almost entirely removed by gravel extraction. A rock cliff shoreline up to 12 m high then continues northeast across former Highway 5 to Cooksville, where another embayment at Cooksville Creek was also isolated by a gravel bar nearly 2 km long. Shorecliffs of till alternate with baymouth gravel bars across the Little Etobicoke and Etobicoke Creek valleys to east of Highway 427. From there the shoreline, of bluffs eroded into till, swings northeast, then north up the Humber River valley to Weston. The Humber River valley formed a major re-entrant in the glacial Lake Iroquois shoreline. The re-entrant became nearly enclosed by a large spit, which grew westward from the till shore bluff across central Toronto, much as the Toronto Islands spit has grown westward from Scarborough Bluffs (Fleming 1853). This gravel ridge, discussed by Fleming (1861), is east of the present map area, but the lagoon area isolated behind it is partly within the area, forming a sand plain south of Weston (*see* Map 2223). In the protected lagoon, shore features are subdued and gentle.

Subsequent to deglaciation, isostatic uplift has tilted the formerly horizontal shoreline of glacial Lake Iroquois up to the northeast, toward the area of formerly thickest ice. Wilkinson's (1959) work determined the direction of maximum tilt to be 021° in this area, with a slope of about 0.4 m/km. The part of the shoreline within the Brampton map area is now entirely urbanized and its gentler parts are difficult to recognize because of the modification of the landscape.

Deltas

Deltas form where sediment comes to rest at the mouths of streams entering standing water. They are the chief indicators of stable water levels in glacial Lake Peel and several levels are suggested by such features in the Brampton map area. The deltas formed in glacial Lake Peel were built by streams flowing off the land toward glacial lakes bounded to the south by the retreating ice margin, so they do not have a glaciofluvial association. The streams were fed by precipitation on the land to the north and west. Deltas were often built in narrow estuarine valley mouths, which affected their shape and growth.

Karrow and Warner (1988) compiled available information on glacial Lake Peel deltas in the Hamilton (Karrow 1987a), Brampton, Bolton (White 1975) and Thornhill (Karrow 1970) areas and compared them to the glacial Lake Iroquois shoreline. Unfortunately, deltas are not numerous enough to clearly define particular water levels. There is uncertainty too in their elevations, which have had to be estimated from 1:25 000 scale topographic maps with a contour interval of 10 feet. More detailed maps with smaller contour intervals, or instrumental surveys, are needed to refine delta elevations. Water levels were estimated from the elevations of the flat tops of deltas near their outer edge where a slope break, often vaguely defined, could be recognized. This was taken to be the boundary between the topset and foreset beds of Gilbert-type deltas. Delta size is dependent on several variables, such as the length of time available for deposition, the volume of sediment supply, size range of the sediment, and the effect of currents and waves in the lake. As already mentioned, wave action in glacial Lake Peel seems to have been weak, so the dominant influence may be attributable to inflowing streams.

In the Brampton map area, the Credit River is the most prominent builder of deltas associated with glacial Lake Peel. A nested set of 3 deltas is represented by a stepped sand plain between Norval and Churchville (*see* Map 2223), with elevations estimated at 216, 207 and 201 m

(Photo 11). A fourth feature near Meadowvale is at an elevation of about 178 m. Areas of sand plain flank the Credit River valley intermittently from Streetsville to Erindale, spanning the elevation range from 162 to 125 m. There is little morphology to suggest deltaic deposition except a possible break in slope near 125 m elevation, not far above the glacial Lake Iroquois level.

Along Etobicoke Creek near Kennedy Road (southeast of Brampton), a small deposit of sand, possibly deltaic, has an elevation near 207 m (*see* Map 2223). Larger deposits northwest of Burnhamthorpe Road appear to have a frontal edge near 140 m.

Because of the extensive glacial Lake Iroquois embayment up the Humber River valley and the small amount of the valley within the map area, there is little opportunity here to document possible deltaic deposits, which are better seen to the north in the Bolton area (White 1975). However, near Thistletown, a possible deltaic feature near 146 m elevation is discernible (*see* Map 2223).

In summary, although there are several features suggestive of former water levels of glacial Lake Peel, there is not good correspondence between levels in different valleys. Of course, in the eastern part of the study area, urban disturbance hinders definition of some features.

Stream Terraces and Flood Plains

Difficult as it is to sort out the deltaic features of glacial Lake Peel, a clear picture of stream terraces is still farther from being realized, again hampered by inadequate topographic data and, in large parts of the area, by urbanization. Detailed instrumental surveys in the valleys are needed to sort out terrace levels, and correlations along valleys, between valleys and with former lake levels.

It is likely that the longer-lasting lake levels, particularly those involving transgressive or rising water levels, should be particularly reflected in the development of terraces up the river valleys. Such development has been documented in the Lake Huron basin in southwestern Ontario (Karrow 1986b) but has not yet been studied in the Lake Ontario basin except for the Humber River valley study of Roberts (1963, *in* White 1975). Along the valleys of the Brampton map area, older terraces are usually of limited extent, but somewhat in proportion to the size of stream and valley.

Intermediate terraces above the modern flood plain, and lower than those interpreted as deltaic, glaciolacustrine or glacial outwash, are evident on the branches of the Credit River near Georgetown and are common downstream to Erindale (*see* Map 2223, unit 14). The most extensive terraces are those on the Humber River near Thistletown, with more south of Weston. Some of the terraces at Thistletown appear to correlate with the glacial Lake Iroquois level at Weston; Roberts (1963, *in* White 1975) identified an Iroquois terrace farther north along the Humber River. Other small terraces can be seen scattered along Etobicoke Creek and near Milton on Sixteen Mile Creek.

Flood plains are near present stream level and are subjected to flooding at varying and irregular intervals. Those streams flowing directly into Lake Ontario have experienced rising base levels caused by continued uplift of the outlet near Kingston. This has caused flooding and aggradation, particularly well displayed by the marshy lower reaches of Etobicoke Creek and the Credit River; in the study area, the Rattray Marsh (*see* Map 2223) developed similarly. The common occurrence of bedrock in the valleys has also affected valley cutting and widening. Where the Credit River follows a buried bedrock valley it is wider and has a broad flood plain, such as from Norval to Meadowvale. Away from the buried valley, where the Credit River is cutting into rock, its valley is much narrower, such as between Glen Williams and Norval, and between Streetsville and Erindale. The Credit River West Branch has a substantial flood plain from Stewarttown downstream to the Georgetown sewage plant, because it is in part following a buried bedrock valley, but has cut a gorge in shale to join the main branch at Norval.

Most streams in the area, even small ones, have developed flood plains, probably because of the subdued relief and downward hindrance to erosion by bedrock close to the surface. Some examples have been noted of streams cutting down in till, but flat glaciolacustrine plain in downstream reaches acted as local base level and fostered flood plain development in the till areas upstream. Several cases can be seen on the Halton Till plain near Milton and northeast of Agerton.

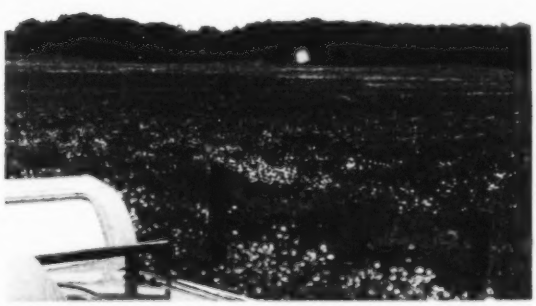

Photo 11. Dissected frontal slope of a Credit River delta, one of a nested set of 3, formed in glacial Lake Peel at 201 m, 2 km south of Huttonville.

Swamps and Bogs

In spite of the generally low relief of most of the area, wetlands are quite uncommon. Most swamps and bogs are found in the rough terrain of the bedrock complex and kame moraine tracts west of the Niagara Escarpment, where rock creates inhibited vertical drainage. The Hilton Falls Conservation Area includes some of these (*see* Map 2223). Small marshes occur in kettle depressions of the Cheltenham moraine. A few swamps occur at widely scattered locations in residual glaciolacustrine depressions between Milton and Huttonville. A prominent fluting containing a swamp in the till plain east of Streetsville has been the subject of recent efforts by conservationists for preservation.

A belt of kettle bogs extends along the Brampton esker (*see* Map 2223), and accounts for the largest and most numerous organic deposits east of the escarpment (*see* Photo 10). Some of these are preserved within the Heart Lake Conservation Area. They are typically situated in steep-sided depressions (kettles).

Lake Ontario Shoreline

Some 14 km of Lake Ontario shoreline extend across the southeast corner of the map area. The shoreline is characterized by low cliffs, commonly 2 or 3 m high, but reaching 15 m at Lorne Park. The cliff is cut in Ordovician shale at the south edge of the area (*see* Map 2223), but elsewhere is formed of glaciolacustrine sand or clay over Halton Till. Watt (1968) described more than one till type in these exposures, but the character of the materials is now extensively concealed by shore protection works such as gabions, riprap, retaining walls, groynes, piers and fill.

STRATIGRAPHY

In this section of the report the various materials or stratigraphic units encountered in the area are described in their determined or presumed order of formation—from oldest to youngest. Although exposures are numerous, few extend deeper than the surface Halton Till, or reveal more than Halton Till over bedrock. Airphotos reveal that some significant exposures were formerly accessible on the Credit River, Humber River and various other streams; many of these have either slumped and become vegetated through natural processes, or have been covered by landscaping associated with urbanization and erosion control. Examination of the stream bank exposures of the Quaternary sediments still available has been supplemented by observations made by others (as listed in Appendix 1) of some now-covered exposures. Additional information was also obtained from a series of test holes drilled in the west part of the study area in 1986.

Descriptions of many of the stratigraphic sections from stream bank exposures, excavations and boreholes are included in appendixes to this report (Appendixes 1 and 2).

Before describing the various stratigraphic units, brief summaries of the known stratigraphy of the important stream valleys are presented in order, from west to east.

Valley Exposures

SIXTEEN MILE CREEK

The Sixteen Mile Creek valley has several exposures that reveal only Halton Till with varying amounts of overlying glacial Lake Peel sediments. In its downstream portion, near the south edge of the map area, Queenston Formation red mudstone forms the lower valley walls under the till (*see* Photo 2). The red mudstone is a northeast extension of a low ridge in the rock surface extending northeast from a Niagara Escarpment salient at Mount Nemo (Karrow 1987a).

CREDIT RIVER

The Credit River valley, extending roughly diagonally across the map area from the northwest corner to the southeast, reveals a variety of materials along its length, although most appear to be young deposits associated with the Halton and the preceding Newmarket glacial advance. The thickest stratigraphic sequence exposed is at Glen Williams, where Halton Till overlies thick glaciofluvial sand. A similar sequence is present to the north along the valley and at Norval, where the lower sand is replaced by gravel. Bedrock outcrops are common downstream as far as Huttonville, beyond which the Credit River valley follows a deep buried bedrock valley to Meadowvale. In this stretch the few exposures reveal only Halton Till under terrace sediments. Rock walls again become common at Streetsville and continue to near Lake Ontario with terrace gravels overlying Halton Till in the upper parts of the exposures. Along its course in western Brampton to where it joins the Credit River near Meadowvale, Fletchers Creek, a tributary to the Credit River, reveals only Halton Till with overlying glaciolacustrine deposits, and occasionally the underlying bedrock.

ETOBICOKE AND MIMICO CREEKS

Etobicoke Creek exposures are mainly Halton Till, with bedrock appearing southeast of Brampton. A few exposures at Brampton reveal a coarser, sandy (Newmarket) till below the Halton. Mimico Creek has few exposures, which reveal Halton Till over Newmarket sandy till at Islington.

HUMBER RIVER

The Humber River has exposed the most complete stratigraphic sequences in the map area, but exposures have deteriorated considerably. Most notable are: 1) the Claireville dam section (measured section B-1018, *see* Appendix 1; discovered by A. Dreimanis, University of Western Ontario, in 1962), with Halton and at least 2 older tills, the oldest of which contained an inclusion of plant debris beyond the range of radiocarbon dating; and 2) the section east of former Highway 27 (measured section B-1014, *see* Appendix 1), in which Watt (1968) identified the York Till (Illinois?) and a sandy lower till (Newmarket) and Halton Till above. Downstream along the Humber River, rising shale walls limit the exposures of Quaternary sediments to the Halton Till, and in some places overlying water-laid silt and gravel. Less than 2 km north of the Brampton map area is one of the most complete stratigraphic sections of the Toronto district, the Woodbridge cut, located on a Canadian National Railway line west of the Humber River valley. It contains Illinois York Till, fossiliferous interglacial sediments, Early Wisconsin Sunnybrook Till, fossiliferous Middle Wisconsin gravels and 3 Late Wisconsin tills (Karrow et al. 2001).

Watt (1957, 1968) referred to as many as 3 Wisconsin tills and the Illinois till in the Humber River valley and in lakeshore exposures, but these are now so generally covered over that his observations and interpretations cannot be reviewed. He showed generalized cross sections in Etobicoke indicating the widespread extent of older tills.

Stratigraphic Nomenclature

Some comment is appropriate here on the nomenclature of tills in this and nearby areas. In 1959, Karrow named the surface till of the Hamilton area the Halton Till, with its type section in the Hamilton map area. Terasmae (1960) named the surface till in central and eastern Toronto the Leaside Till. Karrow (1967), in the Scarborough area, recognized a surface fine sandy to silty till overlying a stony sand till and referred to these as upper and lower Leaside Till. Mapping north and west by Karrow (1970) and White (1975) indicated that Halton and upper Leaside were the same till sheet and Karrow (1974) proposed the name Leaside be dropped in favour of Halton. This left the lower sandy till without a proper designation.

Meanwhile Watt (1957, 1968) and Dreimanis and Terasmae (1958) described an upper silty Wisconsin till, a middle sandy Wisconsin till and a lower clayey Wisconsin till in the Toronto area. The upper can be identified as Halton Till, the middle as the former lower Leaside, and the lower as Sunnybrook Till (Terasmae 1960). The upper and middle tills are believed to be of Late Wisconsin age, while the Sunnybrook is of Early Wisconsin age.

In the Hamilton map area to the south and the Bolton map area to the north, the Halton Till margin lies near or just west of the Niagara Escarpment. Farther west, an older sandy till, the Wentworth Till (Karrow 1959, 1987a) extends westward to form drumlins and the Moffat, Galt and Paris moraines. Rare exposures near the Halton margin reveal sandy till, usually below glaciofluvial sediments under the Halton Till. White (1975) applied the name Wentworth to the sandy till below Halton Till in the Bolton area. The Wentworth Till, however, has a restricted time of formation in its type area to the west, 13 500±200 years BP (Warner and Barnett 1986). However, the "middle" sandy till of the Toronto area appears to represent all of Late Wisconsin time except for the Halton and younger events; that is, spanning the interval from about 23 000 years BP to 13 400 years BP, and thus is similar in time frame to that represented by the Catfish Creek Till in southwestern Ontario (Figure 7). As an interim solution, Karrow (1991) proposed to refer to the buried sandy till by the informal name, Humber till. Subsequent regional work has indicated this till is likely a southwestward extension of the Newmarket Till, now known from extensive study of the Oak Ridges moraine to be a continuous till sheet into the Ontario basin beneath the moraine (Barnett et al. 1998).

Geologic time classifications have also been revised in recent years. This report follows the new diachronic classification of Johnson et al. (1997) and Karrow, Dreimanis and Barnett (2000).

Escarpment Crevice Deposits

Carbonate rocks have the potential for the formation of karst topography as the result of solution by groundwater. Probably as a result of collapse of pre-existing caverns by ice loading, and burial and filling of cavities by glacial deposits, such well-developed solution features are rarely encountered in the dolomitic rocks of the Niagara Escarpment. However, solution-widened joints are common. Some escarpment caves have formed from a combination of solution widening of joints and mass movement of joint-bounded blocks out from the escarpment face, perhaps under periglacial conditions (Straw 1966).

Such caves and crevices have acted to trap animals, whose skeletal remains have been partly cemented in by precipitation of carbonate from water seeping along the joints and bedding planes. The stratigraphy of such deposits can be complex, consisting of insoluble residues (red-brown cave mud), silt, sand, dolostone fragments and dripstone. Generally, the age of these deposits is uncertain and hard to determine, but the process of formation is likely a continuing one. Thus far, 3 sites within, or a short distance beyond, the south edge of the map area have been

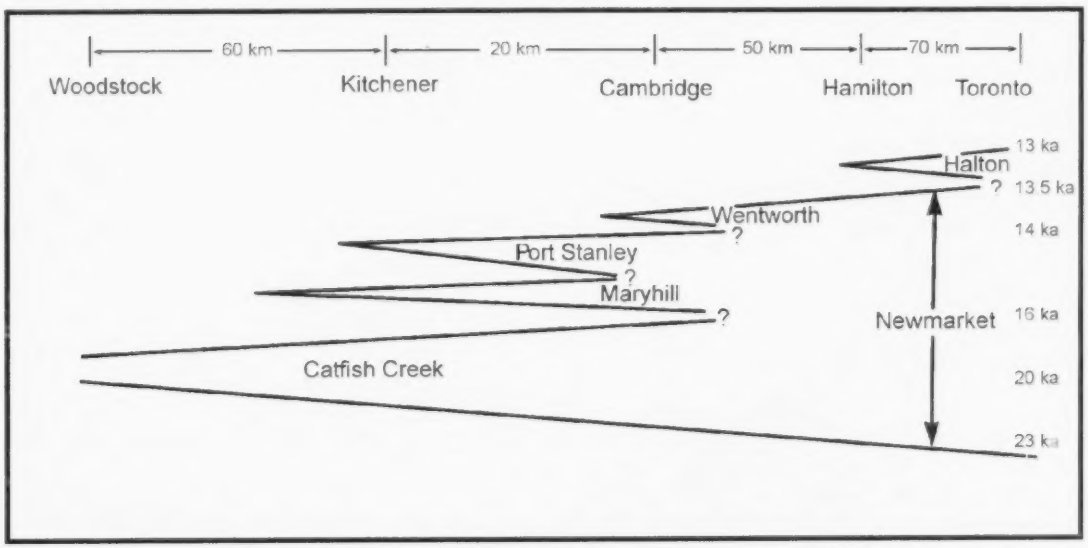

Figure 7. Stratigraphic and time-distance relationship of tills and ice advances between Toronto and Woodstock, Ontario.
Note: ka = thousand years before present.

found and studied. The potential exists, however, for the discovery of similar sites along much of the Niagara Escarpment.

The first site to be reported (Bateman 1961) was from Mount Nemo, about 8 km south of the map area in the Hamilton area, where 4 species of mammal remains were described. Shortly after, Churcher and Fenton (1968) described 12 species of reptiles and mammals (mostly bats and rodents) from a site at the Dickson quarry near Mount Nemo and, because of the presence of wapiti, concluded the deposit was more than 200 years old. Of greatest interest is the third site, at Kelso, on the north end of the Milton outlier and just within the south edge of the Brampton map area (*see* Map 2223). There, a now-abandoned quarry yielded a vertebrate fauna of 9 species (Churcher and Dods 1979), from which the extinct *Ochotona* suggested an age at least as great as Illinois (about 150 000 years). A summary of the species reported at the 3 sites is presented in Table 1.

Excavations along the Niagara Escarpment, such as those in quarries, should be monitored for any further such remains. The Kelso site has indicated the potential for discovery of old and unusual fossil remains at such sites.

York Till

The York Till was named by Terasmae (1960), with its type section at the former Don Valley Brickyard in central Toronto. At the type section it underlies obviously interglacial, fossiliferous Don Formation, but it is commonly concealed by slump there. At the Woodbridge cut (Karrow et al. 2001), just north of the Brampton map area, it is better exposed and underlies thin fossiliferous interglacial sediments; boreholes there reveal deep underlying gravels. The York Till is considered to be of Illinois age.

Watt (1957, 1968) identified Illinois till in western North York Township (now part of the City of Toronto) along the Humber River valley; in northern Etobicoke Township (now part of the City of Toronto) along the West

Table 1. Vertebrates in Niagara Escarpment crevices (compiled from Bateman 1961, Churcher and Fenton 1968, and Churcher and Dods 1979).

SPECIES	LOCATION		
	Mt. Nemo	**Dickson**	**Kelso**
Amphibia			
Bufo ? americanus (American toad)			X
Aves			
? Bonasa umbellus (ruffed grouse)			X
Reptilia			
Chrysemys picta (painted turtle)		X	
Mammalia			
Insectivora			
Blarina brevicauda (short-tailed shrew)		X	
Sorex fumeus (smoky shrew)		X	
Chiroptera			
Eptesicus fuscus (big brown bat)		X	
Myotis keenii (keen's myotis)		X	
Myotis lucifugus (little brown bat)	X	X	X?
Pipistrellus subflavus (eastern pipistrel)	X		
Carnivora			
Mephitis mephitis (striped skunk)			X
Lagomorpha			
Lepus americanus (varying hare)			X
Sylvilagus floridanus (cottontail rabbit)			X
Ochotona sp. (extinct large pika)			X
Rodentia			
Clethrionomys gapperi (red-backed vole)		X	
Microtus pennsylvanicus (meadow vole)		X	
Tamiasciurus hudsonius (red squirrel)		X	
Peromyscus maniculatus (deer mouse)		X	X
Ondatra zibethicus (muskrat)		X	X
Castor canadensis (beaver)	X		
Artiodactyla			
Cervus canadensis (wapiti)		X	
Odocoileus virginiana (whitetail deer)	X		

Humber River; and in southern Etobicoke Township in excavations, river banks and lakeshore exposures. Watt described the till as having "remarkable consistency", with a sandy clay texture and a high percentage of shale clasts. Watt specifically illustrated (Watt 1968, p.2) a section on the West Humber River at former Highway 27 as exposing this till, overlying shale bedrock. However, A. Dreimanis (personal communication, 2003) has heavy mineral data that indicate only Halton and Newmarket tills are present.

Accepting the probable presence of York Till at some of the places mentioned by Watt, this author feels there is a good possibility that other ice advances across the exposed Georgian Bay Formation could produce till resembling typical York Till. Unfortunately, obvious interglacial sediments have not been identified in the area, leaving some doubt about the correct interpretation of till of such character. Watt did his mapping in the 1940s and 1950s when there was much less urban disturbance, and more fresh riverbank sections were available from which to establish the stratigraphy. The results of the present mapping can neither confirm nor refute his interpretation, so it must remain as the best available working hypothesis.

All available information suggests that older deposits rapidly wedge out west of the Humber River valley, leaving mainly deposits of Wisconsin age, or even latest Wisconsin, lying directly on bedrock.

Sunnybrook Till

Clayey to silty till, low in pebble content, with a low carbonate ratio, was referred to as Lower Wisconsin till by Watt (1957) in former North York Township and in former Etobicoke Township (Watt 1968), and by Dreimanis and Terasmae (1958) as an Early Wisconsin glacial deposit separated from Late Wisconsin ice deposits by fossiliferous interstadial deposits and a paleosol. Terasmae applied the name Sunnybrook Till and designated the Seminary gulley at Scarborough Bluffs as its type section. Karrow (1967) mapped its extent in the bluffs and inland along Scarborough valleys. Karrow (1969) included glaciolacustrine rhythmites he named the Bloor Member of central Toronto with the till in Sunnybrook drift. The Sunnybrook Till was recognized northwest of Toronto in the Woodbridge cut (White 1975) and in excavations at York University (Karrow 1970; White 1975).

The depositional origin of the Sunnybrook Till as a true till deposited directly by glacial ice was disputed by Eyles and Eyles (1983) and Eyles, Eyles and Miall (1983), who instead interpreted it as a glaciolacustrine deposit formed in association with floating ice. Much discussion ensued in the literature (Dreimanis 1984a, 1984b; Eyles and Eyles 1984; Eyles, Miall and Eyles 1984; Gravenor 1984; Karrow 1984b, 1984c; Kemmis and Hallberg 1984; Sharpe 1984). Further evidence in support of the glaciolacustrine origin was presented by Eyles, Day and Gavicon (1987) and Westgate, Chen and Delorme (1987), while evidence supporting deposition by grounded ice has been presented by Gravenor and Wong (1987), Sharpe and Barnett (1985), Sharpe (1988) and Hicock and Dreimanis (1989, 1992).

In the Brampton area, this till was identified in the Claireville dam section (measured section B-1018, Appendix 1; Hicock and Dreimanis 1985) and as the lowest of 3 tills in an exposure on Mimico Creek. Although Watt (1968) showed the Sunnybrook Till in cross sections in northern and southern parts of former Etobicoke Township, as is the case for York Till, those exposures are now mostly covered.

At the Claireville site, the till contained an inclusion of sand containing wood that was dated at more than 50 800 years BP (GrN-4237). A sample examined for pollen by Dreimanis yielded the following assemblage: *Pinus* 69%; *Picea* 17%; *Abies* 3%; *Quercus* 2%; *Betula* 1%; *Salix* 1%; *Larix* 1%; non-arboreal pollen 6% (A. Dreimanis, written communication, 1962). This assemblage and the radiocarbon date suggest incorporation of fossiliferous sediment from the Scarborough Formation of central and eastern Toronto, which underlies Sunnybrook Till over large areas. Structural details at this exposure are illustrated and discussed by Hicock and Dreimanis (1985, Figure 3, p.342-343). The section is now completely covered.

A small exposure of probably correlative till can be seen at the base of a section on Mimico Creek (measured section B-4001, Appendix 1), where it underlies 2 Late Wisconsin tills.

The Woodbridge cut is only 1.5 km north of the Brampton map area and exposes large lenses of typical Sunnybrook Till in an unusually complete stratigraphic sequence. It is there underlain by peaty sands correlated to Scarborough Formation, shelly sand (Don Formation) and York Till, and overlain by fossiliferous Middle Wisconsin gravel and peat and 3 Late Wisconsin tills more fully described by White (1975) and Karrow et al. (2001).

Although good stratigraphic evidence of the extent of Sunnybrook Till in the Brampton map area is now little exposed, it is believed to be present through the Humber River valley and much of former Etobicoke Township. Like the York Till, it probably wedges out westward against the rising bedrock surface, but could be encountered in the deep buried valley at Meadowvale.

The age of the Sunnybrook Till has long been considered to be Early Wisconsin. Berger (1984) reported a thermoluminescence date of 66 000 years BP at the Woodbridge cut, which is reasonably consistent with that assignment. Later, Berger and Eyles (1994), from new thermoluminescence analyses, considered this age too old by about 50% and reported new ages of 41 000 to 46 000 years. Underestimation of ages by thermoluminescence dating has become a recognized problem which has not been resolved (Lamothe et al. 1998). Radiocarbon dates from below the unit are all minimum ages and those from above it are either minima or finite in the Middle Wisconsin range (28 000 to 45 000 years BP).

Wentworth Till

Small areas of surface sandy till occur in the northwest corner and west edge of the area beyond the mapped extent of the youngest till (Halton Till, see below). These were identified as Wentworth Till, named by Karrow (1959) and mapped extensively to the west and southwest in Wellington and Wentworth counties, where it forms the Paris, Galt and Moffat moraines and a drumlinized till plain (*see* "Wentworth Till Plain", "Moraines" and "Drumlins and Flutings"). Figure 7 portrays the stratigraphic and historical position of the Wentworth Till in relation to the next older Port Stanley Till and next younger Halton Till. Only 1 sample confidently identified as Wentworth and 4 other possible Wentworth Till samples were analyzed during this study (*see* Appendix 4), the former yielding 58% sand, 37% silt and 5% clay, with some of the other samples being more silty, but compatible with analyses in adjacent areas (e.g., Karrow 1987a).

Wentworth Till is believed to have been deposited during a strong but limited glacial fluctuation during its overall retreat in the warming climate of the Mackinaw Phase. Its limit of advance to the Paris moraine was dated at about 13 500±200 years BP (Warner and Barnett 1986). The retreat of Wentworth ice uncovered the first land area of the Brampton sheet along its western edge, west of the Niagara Escarpment.

Newmarket Till

In several valley exposures and some boreholes, a stony, sandy till underlies the surface Halton Till. Coarse till in this position has been observed along Etobicoke Creek near Brampton, Mimico Creek and the Humber River. Boreholes suggest its presence between Brampton and Highway 401 and other boreholes suggest a similar stratigraphic interpretation south of Milton in the Hamilton map area. A borehole in the Brampton esker suggested its presence at depth (Karrow, Harrison and Saunderson 1977). The rationale for naming this till has been presented in the introduction to the stratigraphy section of this report (*see* "Stratigraphic Nomenclature").

The name Humber till, after the Humber River and valley where it is best exposed in this area, was proposed by Karrow (1991) as an interim informal name for the coarse-textured till below the surface Halton Till. Similar till in this stratigraphic position is known from the work of Watt (1957, 1968), Dreimanis and Terasmae (1958), Karrow (1967, 1970), Dreimanis (1969), White (1975) and Westgate (1978). As previously mentioned, it now seems more reasonable to equate this till with the Newmarket Till of the Lake Simcoe area, a regional till sheet representing about 10 000 years of Late Wisconsin time. The section on the West Humber River at former Highway 27 (measured section B-1014) is considered to be a local reference section, along with section B-4001 on Mimico Creek, an additional reference section (*see* Appendix 1 for section descriptions).

Field exposures reveal that this till commonly contains small lenses of sand, which suggest basal melt-out origin. Larger lenses and masses of sand and gravel are also present. Analyses of 12 samples thought to be of this unit averaged 45% sand (range 39 to 57%), 45% silt (range 34 to 54%) and 10% clay (range 5 to 16%), with matrix carbonate value of 23% (range 7 to 28%) and a calcite/dolomite ratio of 1.7 (range 0.9 to 2.9) (Appendix 4). Southwest-oriented fabrics have been determined at some exposures of this till to the north and northeast of the current study area (Karrow 1970; White 1975).

This till is believed to represent much of Late Wisconsin time, spanning the time from the end of the Middle Wisconsin, about 23 000 years BP, to the Mackinaw Phase, somewhat over 13 000 years BP. Although probably equivalent till has been recognized over a large area, it is locally not well exposed and there remain uncertainties about its origin. Newmarket Till was named by Gwyn (1972), and previously distinguished by White (1975) as the "northern lower till". It is now correlated with an intermediate till, the Bowmanville till in bluffs east of Oshawa, and equivalent till northeast of Scarborough has been referred to as Northern till in several publications (e.g., Gerber and Howard 1996; Boyce and Eyles 2000). Some exposures have revealed multiple till layers of both regional (southwest fabric) and Ontario lobe (northwest fabric) ice flow (Godin et al. 2002; A. Dreimanis, personal communication, 2003).

Maple Formation

White (1975, p.65) proposed the name "Maple Formation" for varied sediments under the Halton Till, exposed in valley sections or road cuts, or as inliers projecting from below through to the surface of the Halton Till. He did not describe a type section but took the name from exposures near Maple, where large sand and gravel pits were active. White (1975, p.65) expressed the opinion that "further study both within and without the [Bolton] map area should be made before a formal name is proposed." Duckworth (1979) formally proposed the name "Goodwood Formation" for outwash sediments between Halton Till and lower (Newmarket) till on the south flank of the Oak Ridges moraine, equivalent deposits at the surface on the moraine crest, and similar sediments between Kettleby and Newmarket tills on the north flank of the moraine. He also neither designated nor described a type section. Duckworth (1979, p.1105) recognized the possible equivalence of the Maple and Goodwood sediments but felt that they "should remain separate until more is known about the relationships between the deposits in the Bolton area and those in the Oak Ridges Moraine."

This writer prefers to use the informal name Maple formation because of its priority; the greater proximity of the Maple area to the current study area; and the stratigraphic continuity that can more readily be demonstrated between the abutting Bolton and Brampton map areas. Occurrences of equivalent sediments in the two areas are very similar.

In the Brampton map area, scattered occurrences of sand under the Halton Till, or projecting through as inliers, extend across much of the area, but are particularly evident in a belt extending diagonally across the area from Scotch Block (northwest of Milton) to Weston. Thick deposits (30 m or more) are shown in east-to-west cross sections of the Humber River valley (Watt 1968) and as a northwesterly thickening (30 m) wedge up the Humber River valley (Dreimanis 1969). Funk (1979) shows the extent of a buried sand aquifer in the upper Sixteen Mile (Oakville) Creek basin north of Milton. Hickinbotham (1979) shows the extent of a channel-fill aquifer along the buried "Meadowvale Valley". Thick deposits of gravel, sand and clay are known from exposures along the Credit River valley northwest from Norval, and the Brampton esker is believed to be an elongate lens of sand and gravel in this stratigraphic position. It is also known that bedrock highs, commonly covered only by Halton Till, separate some of these sediment bodies. Parts of these deposits could be considered lateral facies members of the broadly defined, generalized Maple formation; thus, there could be recognized Weston, Georgetown and Brampton members, for example. With much more detailed subsurface information it will likely be possible to define these sediments more formally, but the single grouping under the Maple formation is convenient at this time. For simplicity at the present scale of mapping, most of the deposits are classed as ice contact (*see* Map 2223, back pocket).

The sedimentology of gravel, sand and clay under the Halton Till along the Credit River valley between Norval and Cheltenham has been described in some detail by Costello and Walker (1972). They considered the sequence to consist of outwash gravel and sand associated with the retreat of Wentworth (Newmarket) ice, overlain by glaciolacustrine clays deposited in an ice-dammed lake in the Credit River valley north of Glen Williams, all overridden and capped by Halton Till. A similar fining-upward sequence of outwash followed the Halton retreat. Overall, the sedimentary environment was that of a braided stream, with longitudinal gravel bars up to 3 m high, followed by the formation of dunes and wide linguoid or transverse bars of sand. In 1985 an excavation in Georgetown exposed glaciolacustrine clay and silt below Halton Till (Photos 12 to 15); the clays are probably correlative with those north of Glen Williams.

The sedimentology of the Brampton esker was studied in detail from the many pit exposures by Saunderson (1975; Saunderson *in* Karrow, Jopling and Martini 1982), who concluded that deposition took place into an ice-front re-entrant bordering a glacial lake. While variable in detail, overall paleocurrents deduced from bedding structures were to the northwest. Ice-contact glaciofluvial sand and gravel were deposited contemporaneously with glaciodeltaic and glaciolacustrine gravel, sand, silt and clay. Further interest in the deposit was added by the discovery of detrital plant remains (fruits of *Potamogeton pectinalis*, *P. nodosus*, *Brasenia shreberi*, *Nuphar* sp., wood of angiosperms, *Picea*, and *Larix* cf. *L. laricina* and pollen dominated by *Pinus* (63%) and *Picea* (18%)—identified by J.V. Matthews Jr. and R.J. Mott, Geological Survey of Canada,

Photo 12. Large cut (measured section B-2633) east of Mountainview Road in northern Georgetown exposing Halton Till (upper 2m) over glaciolacustrine clay of the Maple formation.

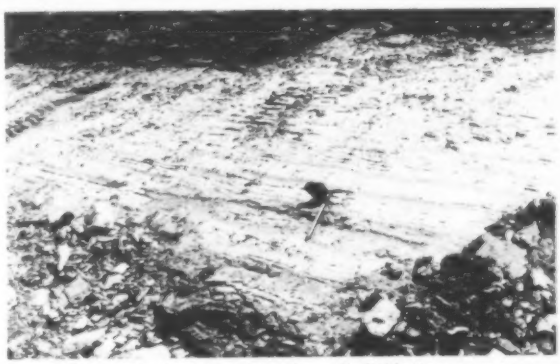

Photo 13. Glaciolacustrine clay at B-2633, Georgetown.

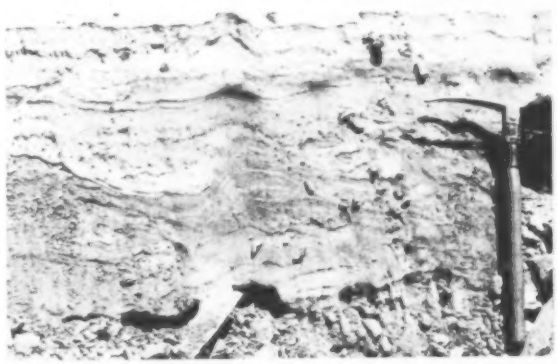

Photo 14. Detail of disturbed bedding in glaciolacustrine clay at B-2633, Georgetown.

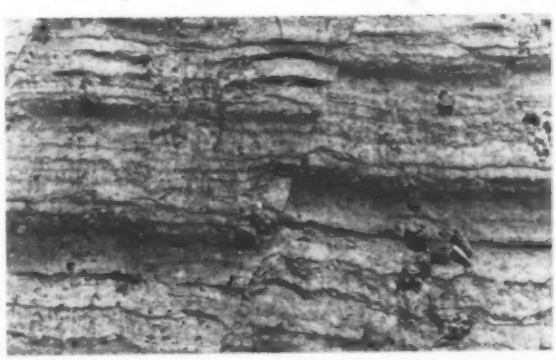

Photo 15. Fault in glaciolacustrine clay at B-2633, Georgetown.

personal communication). A piece of wood was dated at greater than 41 200 years BP (BGS-184: Karrow, Harrison and Saunderson 1977), courtesy of J. Terasmae, Brock University. Although these remains are in deposits probably of Mackinaw Phase age (about 13 500 years BP) the date shows they are probably reworked from an older deposit of Middle Wisconsin or older age (Karrow, Harrison and Saunderson 1977).

The deposits of the Humber River valley consist predominantly of sand, with some clay and gravel. Watt (1968) suggested these deposits may represent deposition in a lake between the middle (Newmarket) and upper (Halton) ice advances and probably include deltaic and nearshore sand. As with the postglacial lake deposits, sediment may have been derived mainly from meteoric runoff southeastward rather than (or as well as?) from glacial sources to the southeast.

The body of sand north of Milton seems to be an irregular sheet-like deposit with very limited exposure in a few small pits. Pollen recovered from organic silt and sand under Halton Till at B-3035 (*see* Appendix 1) near the southeastern edge of this deposit yielded the following assemblage (percentages based on tree pollen count; tr = trace): *Pinus* 61%; *Thalictrum* tr; *Picea* 36%; *Cyperaceae* 1%; *Abies* 1%; *Osmunda* tr; *Betula* tr; *Pediastrum* tr; *Quercus* tr; *Glomus* 3%; *Carya* tr; pre-Quaternary spores 2%; indeterminable and unknown 1% (B.G. Warner, University of Waterloo, personal communication). Total pollen concentration was calculated as 67 881 grains/cm^3. This assemblage, dominated by pine and spruce, is like those of most interstadial sites and indicates little as to the age of the deposit. A boreal environment may be inferred. The enclosing sediment is thought to be of Mackinaw Phase age; no datable organic matter was found.

In summary, the sediments of the Maple formation are a varied assemblage of ice-contact (Photos 16 and 17), outwash and glaciolacustrine deposits. These deposits represent rapid sedimentation over wide areas during the ice retreat of the Mackinaw Phase between deposition of the Newmarket and Halton tills, and have an age of 13 000 to 13 500 years BP. They are distinctly younger than the somewhat similar sediments of the Middle Wisconsin Thorncliffe Formation of the Scarborough area (Karrow 1967), although glaciolacustrine sediments are more prominent in the latter. According to present interpretations, Thorncliffe and Maple formations are separated by the Newmarket Till. Some intertill sediments of the Brampton area may be equivalent to the Thorncliffe Formation but have not yet been specifically identified as such.

Halton Till

The youngest glacial deposit in the Brampton area is identified as the Halton Till, because of its mapped continuity with the type section (near Lowville, in the Hamilton map area to the south) and the type area in Halton County, after which it was named (Karrow 1959). The Halton Till occurs at or near the surface over most of the area, the major exceptions being beyond its westward limit west of the Niagara Escarpment; where it was subsequently eroded along stream valleys; and where it is covered by younger deposits, particularly those of glacial lakes Peel and Iroquois. Because of its widespread distribution and occurrence at or near the surface, most till samples collected during this survey are of the Halton Till.

The appearance of the Halton Till varies with the nature of the underlying bedrock. Thus, east of the contact between the Georgian Bay and Queenston formations the till is grey to olive in colour, whereas west of that contact it is purple to red-brown. East of the Niagara Escarpment the coarse fraction is dominated by flaggy and tabular Ordovician shale and siltstone, whereas west of the escarpment more equant dolostone clasts become evident.

The till matrix is typically fine-grained and displays desiccation cracks on exposure; weathered cuts develop a

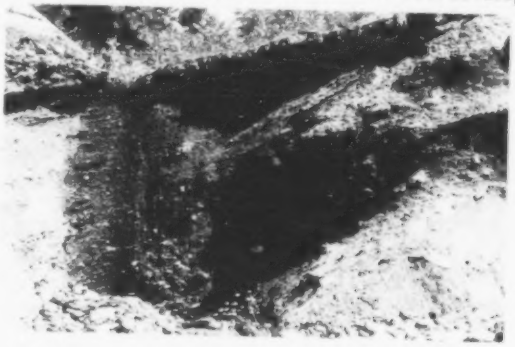

Photo 16. Foreset bedding in ice-contact (?) gravels of the Maple formation at field station 2646, Glen Williams.

Photo 17. Detail view of poorly sorted, subangular gravel of the Maple formation at field station 2646, Glen Williams.

till pattern and surface clast concentrations. Analyses of 55 samples (*see* Appendix 4) average 25% sand (range 8 to 49%), 52% silt (range 42 to 65%) and 21% clay (range 7 to 44%). This can be generalized by saying the matrix is half silt with subequal proportions of sand and clay, or that it is a sandy silt to clayey silt till. These values are similar to, but slightly coarser than those of the Hamilton area (Karrow 1987a). The variation is probably attributable to the overriding of finer glaciolacustrine sediments nearer to the axis of the Lake Ontario basin during the Halton advance. Plots of grain-size analyses show no general trend across the area but local anomalies have been noted. Areas of clay-rich and low-stone-content till occur north of Georgetown and southwest of Terra Cotta. Particularly sandy facies have been noted at Norval and Erindale and along the buried Credit River valley where the ice evidently overrode previously deposited glaciofluvial sediments.

The carbonate content of 53 samples of Halton Till averaged 21% (range 8 to 32%) with a calcite/dolomite ratio of 2.6 (range 0.7 to 9.4; *see* Appendix 4). The relatively low carbonate content is no doubt attributable to the heavy incorporation of local shale, which has a low carbonate content.

The thickness of the Halton Till varies from 0.0 m where it wedges out over underlying sand or bedrock, to more than 10 m. The Halton Till overlies older till (Wentworth or Newmarket), intervening glaciofluvial and glaciolacustrine sediments or, quite commonly, bedrock. It is commonly overlain by glaciolacustrine sediments of glacial Lake Peel, into which it often grades through complex facies of debris flows. South of the glacial Lake Iroquois shore bluff, it is commonly separated by an erosional unconformity from younger glaciolacustrine sands and clays of glacial Lake Iroquois.

Halton Till has been mapped to the south of the study area across the Hamilton area (Karrow 1987a) and through the Niagara Peninsula (Feenstra 1974, 1975, 1981), and to the north and east (Karrow 1967, 1970; White 1975; Westgate 1979). It is older than glacial Lake Iroquois, which is dated at about 12 000 to 12 500 years BP, and is considered to represent the Port Huron advance of about 13 000 years BP. This, the last known major advance of the Lake Ontario ice lobe, advanced against the south slope of the Oak Ridges interlobate moraine to the north of the map area and barely surmounted the Niagara Escarpment in the Brampton and Hamilton areas.

Late Glacial Glaciofluvial Deposits

Because of their limited distribution, all surface glaciofluvial deposits younger than the Wentworth or Halton tills are lumped together for this discussion. These deposits are dealt with separately here from deposits of similar origin that underlie the Halton Till in many places. Where the Halton Till has been removed by meltwater erosion, the older and younger deposits may be juxtaposed and difficult to separate. Some surface deposits on the Wentworth Till are likely nearly coeval with deposits under the Halton Till.

Ice-contact deposits are the earliest formed and most closely associated with the glacial environment. In the map area, these are concentrated in the northwest corner, mainly west of the Niagara Escarpment and north of Limehouse (*see* Map 2223, units 6 and 7). Deposits associated with the Wentworth Till cannot be readily separated from those associated with the Halton Till, other than on a geographic basis, aided by some stratigraphic indications. Based on experience elsewhere, greater volumes of glaciofluvial sediment are generally associated with coarser-textured till than with finer-textured till, and thus the Wentworth or Newmarket ice is a probable source. Nevertheless, ice-contact gravels associated with Halton Till are present west of Georgetown and Stewarttown.

The ice-contact gravels near the Niagara Escarpment consist of concentrations of shale and siltstone from the Upper Ordovician and Lower Silurian clastic formations with some admixed carbonate and Precambrian clasts. Because the shales and siltstones weather and break down so readily, the resulting gravels are commonly "dirty" and include some admixed clay, some of which could also have been derived from turbid meltwaters. They are commonly reddish in colour due to the presence of material from the Queenston Formation.

The topography of the ice-contact gravels is typically hummocky and irregular, or "kame and kettle". Most are formed into irregular ridges oriented north-northeast, parallel to the escarpment and a former ice margin, and form part of the Acton moraine of Straw (1968). The post-Halton deposits near Georgetown are oriented northwest and do not appear to relate to ice-margin trends. Other minor ice-contact bodies occur scattered along the Middle Sixteen Mile Creek valley and in the Campbellville re-entrant west of Milton (*see* Map 2223).

Glaciofluvial outwash deposits of sand and gravel were deposited by meltwaters farther removed from the glacier. They are typically better sorted and "cleaner", and have simpler, more level topography. These deposits are more restricted in extent than ice-contact deposits and occur north and east of Limehouse and in the Campbellville re-entrant. Distinction from ice-contact deposits has been made on the basis of topography and internal constitution where visible, but the two classes of deposit grade from one to the other.

A gravel pit 1.6 km southwest of Limehouse in 1984 exposed 5 m of well-stratified, matrix-supported, medium, rounded gravel (Photos 18 and 19). Prominent and simply structured foreset bedding parallel to the ground surface (*see* Photo 19) indicated current flow to the west, toward the Acton re-entrant in the Niagara Escarpment. At Silver Creek, northwest of Georgetown along former Highway 7, another outwash gravel body was the site of an extensive pit that revealed 5 m of sand and gravel arranged in 2 superimposed fining-upward cycles (boulders to sand). Some faulting and bed sagging indicated the

former presence of trapped ice blocks. Paleocurrents appeared to have been westward.

Glaciolacustrine Deposits

The principle deposits of former glacial lakes occur under areas of lake plain widely distributed across the study area. Their distribution has already been described (*see* "Lake Plains" in the "Geomorphology" section of this report). Most common are silt and clay, usually laminated and often displaying cyclic deposition or rhythmites. Deposits are often thin (<1 m) and discontinuous. Only deposits greater than 1 m in thickness are shown on accompanying Map 2223 (back pocket). Deposits have been encountered that are over 4 m in thickness but most are less than 3 m. As these deposits are usually at the surface, their primary structures are modified by pedologic processes in their upper parts and original stratification may be difficult to see. The resulting massive deposit may appear till-like.

Lamination in these deposits is often thin (1 cm or less) and suggestive of starved basin sedimentation. Such stratification was noted in the lake plain east of Brampton. More generally, the rhythmites resemble the graded, fining-upward bedding of varves. No long sequences were seen, with cycles numbering usually only in the tens or twenties.

Other common features are scattered clasts of varied sizes, from sand grains to cobbles, thought to have been ice rafted. The coarse basal parts of the rhythmites are often conglomeratic or contain abundant small clasts, often consisting of chips of silt, clay and diamicton, some of which are rip-up clasts. Sometimes layers and larger masses of diamicton are present and some of the more massive deposits can be interpreted to have originated as debris flows. Commonly, such evidence of glacial influence is most prominent in the lower parts of the glaciolacustrine sequence and a gradation from glacial to glaciolacustrine deposition during ice retreat can be inferred. Similar glaciolacustrine deposits in central Toronto have been described by Lajtai (1967) and were related by him to turbidite deposition. In the Brampton area, sediment transport into the shallow ice-marginal glacial lakes was effected by both meltwaters flowing northwestward from the melting glacier and by meteoric waters running off the higher land north and west of glacial lakes Peel and Iroquois.

In weathered exposures, some glaciolacustrine clay deposits may be mistaken for till. They commonly display *desiccation* cracks caused by shrinkage of clay during drying, and the surface may be lightly strewn with clasts, which are ice rafted but become concentrated on the water-washed surface. Careful examination of cleaned surfaces, particularly when left to partly dry, will often reveal faint or well-developed lamination. Small irregular carbonate concretions are often present on weathered excavated surfaces of glaciolacustrine material, but are rarely encountered on till.

In contrast to the silt and clay deposits associated with deeper-water deposition, shallow-water sediments are not areally extensive. Most prominent, no doubt because of its large extent and vigorous wave action, are the fine sand to silty sand nearshore deposits of glacial Lake Iroquois. These deposits are nearly ubiquitous on the Iroquois terrace in the southeast part of the map area, where they are in some places over 10 m thick (*see* Map 2223, unit 12). They are commonly well stratified and typically have a level surface, gently sloping down to the present shoreline. These deposits are easily eroded by streams and waves, and readily affected by basal piping where they overlie impermeable bedrock, till or glaciolacustrine clay. They are, therefore, commonly deeply dissected, as in the Lorne Park area. The probable sources of this sediment are shore erosion of till bluffs along the glacial Lake Iroquois shoreline and streams such as the Humber River and Credit River.

Nearshore sand deposited in glacial Lake Peel has limited areal extent, and is found in only a few areas. Such deposits occur above the glacial Lake Iroquois shoreline north of Cooksville and as shoreline deposits southeast of Agerton (*see* Map 2223, unit 12). Nearshore sediment also occurs as laminae and interbeds of fine sand with silt and clay around the margins of some areas of glaciolacustrine plain, but are too limited in extent to map.

Deltaic sand and gravel includes a range of sediments from fine sand and pebbly sand, to sandy fine to medium gravel, and occurs most prominently along the flanks of the Credit River valley between Norval and Meadowvale (*see* Map 2223, unit 12). These deposits are generally only a few metres thick. Because of longer transportation, they are usually clean and well sorted, and well stratified. Internal structure is little exposed because the deposits are thin, low in gravel content, and have been valued for specialized

Photo 18. Gravel pit in planar, horizontally bedded outwash gravel southwest of Limehouse.

Photo 19. Well-developed bedding in outwash gravel southwest of Limehouse.

farming such as fruit growing, so have been little exploited for aggregate.

Beach gravel (*see* Map 2223, unit 13) occurs commonly along the glacial Lake Iroquois shoreline at valley mouth re-entrants where baymouth bars were built by wave action. A large Iroquois bar across the Credit River valley (Photo 20) was formerly the site of gravel pits at Erindale. These pits are now largely worked out and the remainder of the gravel is covered with housing. The gravels in these pits were composed of flaggy siltstone and were up to 8 m thick. Exposures seen in 1957 near the west end of the bar revealed beds of red-banded clay, up to 30 cm thick about 6 m below the gravel bar surface, containing the freshwater molluscs *Pisidium compressum*, *Fossaria galbana*, *Valvata tricarinata* and *Probithinella lacustris* (Karrow, Clarke and Herrington 1972). The clay beds probably represent lagoonal or back beach depressional deposits buried by onlapping gravels in rising levels of glacial Lake Iroquois. These fossiliferous deposits, formed about 12 000 to 12 500 years ago, are among the earliest fossiliferous glaciolacustrine deposits known in southern Ontario. Housing excavations examined in 1987 revealed only a few shell fragments and one worn *Pisidium* in sand.

Other glacial Lake Iroquois gravel bars are festooned across shoreline re-entrants north of Cooksville, and across Little Etobicoke and Etobicoke Creek valleys near Dixie Road and Highway 427, respectively. A major baymouth bar built part way across the Humber River valley from the east lies east of the study area.

In the eastern Scarborough area, Karrow (1967) concluded that wave action was particularly evident to about 10 m below the glacial Lake Iroquois shoreline. Farther below the shoreline, relatively unmodified drumlinized till plain was preserved, with deep-water clays in the lowest areas between drumlins. In that area, the Iroquois shoreline swings further inland, and because the shoreline rises to the northeast as a result of isostatic tilting, there is a greater vertical separation (60 m) between the former glacial Lake Iroquois and present Lake Ontario shorelines. In the Brampton map area the separation is about 45 m and the terrace is narrower, so such a relationship is less evident. As can be seen north of the Iroquois shoreline, the till plain in the Brampton map area is of low relief and formed a nearly level surface on which deep-water clays were deposited offshore. These are exposed only in a narrow fringe along the present lakeshore east of the Credit River.

Glaciolacustrine deposits usually rest on Halton Till and are usually the youngest deposits where they occur. Minor reworking by wind of nearshore sands into small hummocks has been noted in a few places, but such morphology is now generally obscured by urban disturbance.

Alluvial Deposits

Stream deposits are areally restricted to terraces and flood plains of postglacial valleys. Such deposits are commonly thin (1 to 3 m), and seldom extend more than 100 to 200 m laterally from streams. As a result of their limited extent and generally poor quality, they have been little exploited as aggregate sources and knowledge of their internal character is mainly based on stream-bank exposures.

Terraces are abandoned portions of former flood plains and increase in age with height above present streams (Photo 21). At their highest, they grade into glaciofluvial outwash formed in the periglacial environment, or into deltaic deposits formed in the declining phases of glacial Lake Peel. Near present streams, they grade down into modern flood plains. At both ends of the sequence, separation of older alluvium from other deposits may be difficult in individual cases.

Deposits typically consist of fining-upward sequences, the coarsest basal material sometimes being a lag concentrate of boulders or cobbles derived from the erosion of underlying till. Overlying sediment consists of varying proportions of stratified gravel and sand, often capped by silt and clay in a soil profile, originating from the last quiet-water deposition.

Modern flood plains include the areas of still active alluvial sedimentation and reworking that are at least occasionally subject to flooding. Deposits on the flood plain typically extend below present stream level (Photo 22). Lithologically the deposits are similar to those on older terraces, but tend to be more poorly sorted and contain a greater abundance of organic matter, much of which is de-

Photo 20. South bank of Credit River at Erindale exposing glacial Lake Iroquois bar sand and gravel overlying Ordovician shale.

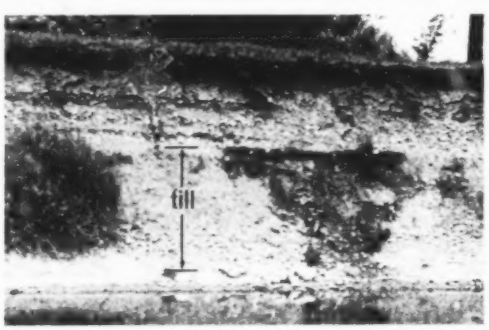

Photo 21. Older alluvial sand and gravel overlying till in the south bank of the Credit River near Meadowvale.

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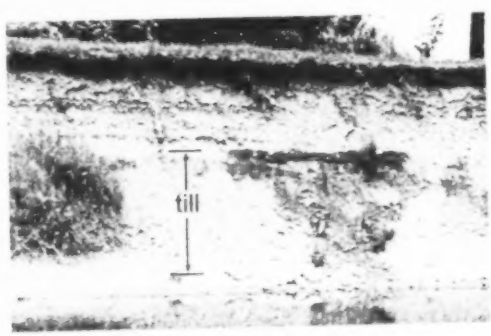

Photo 21. Older alluvial sand and gravel overlying till in the south bank of the Credit River near Meadowvale.

Photo 22. Young alluvium on flood plain of Etobicoke Creek near Burnhamthorpe Road.

trital flood deposits, including logs. Some organics represent accumulation in sloughs in recently abandoned channels.

Continued isostatic tilting of the Lake Ontario basin is causing a long-term rise in lake levels and flooding of the lowest reaches of present streams and their flood plains. The Credit River is a good example of this phenomenon.

Organic Deposits

Depressions with inhibited drainage have been the sites of organic accumulations, such as peat and muck, in many parts of the study area. Probably such deposits were more widespread before the agricultural disturbance of the last 150 years brought about forest clearance and increased drainage. These activities resulted in degradation of the more extensive thinner deposits, leaving only the deeper deposits to survive. Although such deposits are a prime source of paleoecological data for the postglacial period, few sites have been studied in detail in the area.

Organic deposits are comparatively abundant in only 2 parts of the map area. The deepest are those in kettles along the Brampton esker. These occur in a belt from south of former Highway 7 (Queen Street in Brampton) northwest along Heart Lake Road through Heart Lake Conservation Area, and just beyond Mayfield Road at the north edge of the map area (*see* Map 2223). Several kettles and associated bogs and swamps are within the Heart Lake Conservation Area, whereas many others have been destroyed by gravel pit operations and urban construction. Some of these deposits were about 2 m deep but one east of Heart Lake is at least 5 m deep. The largest are probably deeper still. One of the smaller kettle bogs on the crest of the Brampton esker was intersected by gravel extraction in the former Armbro Aggregates pit north of Bovaird Drive. The basal 1.5 m of peat, gyttja and silty clay overlying Halton Till were studied by Terasmae and Matthews (1980). The authors reported ^{14}C dates of 12 320±360 years BP (BGS-551) on white spruce cones (*Picea glauca*) from the gyttja, and 11 970±150 years BP (BGS-550) on moss in the overlying basal peat. The additional 2 m of overlying peat was not studied, but pollen assemblages in the studied sediments were dominated by spruce and pine with low pollen abundance. An adjacent kettle deposit yielded a rich record of fossil insects through the time interval 12 000 to 5000 years BP (Motz and Morgan 1997, 2001).

A few small but similar kettle bogs occur northwest of Georgetown. One deposit in the area, exposed by gravel extraction, was the subject of a study by Warner, Kubiw and Karrow (1991). Pollen and plant macrofossils from peat and clay in the kettle depression range in age from over 11 700 to less than 8700 years BP. The surface of the bog has been disturbed by excavating equipment.

The other main group of organic deposits is that west of the Niagara Escarpment, where scattered shallow deposits (1 to 2 m deep) occur in depressions in the bedrock south of the Acton re-entrant, or associated with ice-contact kame gravels and meltwater channels north of the Acton re-entrant. In the area of potholes and small rock gorges seen in the Dufferin Aggregates quarry in 1984 (*see* Photos 6 and 7), pockets of solid brown peat were seen in section; these have since been removed by quarrying.

An isolated peat body, of uncertain origin, formerly existed at the intersection of Eglinton Avenue West and Kennedy Road in Mississauga. When visited by the author in 1987, the remnants of this deposit exposed 1.5 m of woody fibrous peat. Probing revealed another 0.6 m of peat below the exposed face over at least 0.6 m of silty sand. An extension of this bog to the west along a channel depression was underlain by 1.2 m of peat. Local reports indicated up to 2.4 m of peat formerly existed south of Eglinton Avenue before construction of housing there, and this may have been the source of peat seen stockpiled in 1987 in an old gravel pit (excavated to exploit older alluvial gravels) west of Etobicoke Creek and south of the Canadian Pacific Railway line and former Highway 5. The main body of peat appeared to be situated on a gentle rise, unlike most bogs, which are in depressions. A piece of wood from a depth of 0.9 m in the deposit yielded a ^{14}C date of 8280±160 years BP (WAT-1783) but the deposit has received no further study.

Finally, a deposit of small extent but potentially very significant location, was found at Erindale, west of Mississauga Road and north of Dundas Street West. At the time of mapping, the site was parkland in a small valley tributary to the Credit River and appeared to be located on lagoon sediments behind a large glacial Lake Iroquois gravel bar. The deposit consisted of 1 m of black muck over brown peat, over 0.8 m of sand, silt and clayey bands with some mollusc shells. The deposit was sampled by the author and B.G. Warner, University of Waterloo, but the samples have not yet been studied to assess any association with glacial Lake Iroquois. The site was later destroyed by urban construction.

Marshes underlain by unknown depths of organic sediment occur in the estuaries of the major streams flowing into Lake Ontario. Such deposits are particularly evident at the mouth of Sheridan Creek (Rattray Marsh), the Credit River at Port Credit, and Etobicoke Creek west of Long Branch. A baymouth bar presently isolates a small lagoon and the Rattray Marsh from Lake Ontario. Deep accumulations of organic-rich muds probably underlie these

drowned stream mouths as a result of the long-term rise of water level in the west end of Lake Ontario, brought about by uplift of the outlet near Kingston, Ontario.

Studies of the sediments, their contained fossils and ages, have been published for Grenadier Pond near the mouth of the Humber River, east of the map area (McCarthy and McAndrews 1988); the lower Humber River (Weninger and McAndrews 1989); Hamilton Harbour (Karrow, Clark and Terasmae 1961; Karrow 1987a; Coakley and Karrow 1994); and Sixteen Mile Creek lagoon, near St. Catharines in the Niagara Peninsula (Flint, Dalrymple and Flint 1988).

Lake Ontario Deposits

The only deposits of Lake Ontario that are presently exposed are narrow, thin beach deposits along the present shore. Most of the natural shore has been covered and disturbed by fill and riprap and structures designed to impede shore erosion or create new land. Beach bars in a relatively undisturbed setting occur in front of the lagoon of Rattray Marsh. Beach sediment is typically well-sorted sand.

Offshore, studies by Rukavina (1969) to water depths of 20 m reveal extensive areas of exposed or only thinly covered shale bedrock. A belt of sand parallels the shore at Port Credit with a small area of glacial sediment out from Rattray Marsh. Beyond 20 m depth, details of sediment distribution are much less well known. However, Thomas, Kemp and Lewis (1972) show a broad area of undifferentiated bedrock and/or glacial deposits extending eastward to Humber Bay, where the surface sediments of a thick fill in a buried bedrock valley are shown to be silty muds by Lewis and Sly (1971).

HISTORICAL GEOLOGY

Study of deep-sea cores has revealed that about 20 cold periods, probably accompanied by glaciation on the continents, have occurred in Quaternary time. Evidence of only the last 2 is known in the Toronto area.

The Quaternary deposits of the Brampton area include probable Illinois York Till and Illinois vertebrate remains in escarpment crevice deposits, about 150 000 years old. It is known that Illinois glaciation covered the Great Lakes area and deposited multiple tills in the US Midwest. The York Till, and associated varved clay lake deposits in central Toronto, are believed to be the local representatives of that glaciation. The climate subsequently warmed and interglacial conditions prevailed for thousands of years, at which time (about 125 000 years ago) the fossiliferous Don Formation was laid down in the estuary of a large river flowing from the north. No interglacial sediments have been discovered in the Brampton map area, although they are sparingly represented at the Woodbridge cut north of the study area (Karrow et al. 2001). The subsequent cooling, well represented in Toronto by the deltaic Scarborough Formation and by several metres of peaty sand at Woodbridge, is also not known from the Brampton area.

Early Wisconsin glaciation is represented by the Sunnybrook drift of the Toronto area, and a few exposures of Sunnybrook Till in the Brampton area along the Humber River valley record its presence. There is uncertainty about the extent of this phase of glaciation but it probably covered at least the Lake Ontario basin. A long subsequent interval of glacial withdrawal during the Middle Wisconsin, 60 000 to 20 000 years ago, is also not known from the Brampton map area but is represented at Woodbridge by a few metres of fossiliferous gravel containing bones of bear and mammoth, and peat and thick stream and lake deposits of the Thorncliffe Formation at Toronto.

The strong Late Wisconsin advance, which reached its southern limit along the Ohio River in the United States, deposited the Catfish Creek Till of southwestern Ontario and the Newmarket Till of the Brampton map area. During its fluctuating retreat, numerous distinguishable till sheets were formed by the Late Wisconsin glacier (e.g., the Maryhill, Port Stanley and Wentworth tills of the Erie–Ontario lobe) during formation of the Newmarket Till (*see* Figure 7).

Withdrawal of the ice during the Mackinaw Phase (about 13 500 to 13 000 years ago) uncovered the Brampton area for the first time since the Middle Wisconsin. During this interval the varied ice-contact, outwash and glaciolacustrine deposits of the Maple formation were deposited in the Brampton area. The pollen-bearing sediments at Erin Mills were probably formed at this time.

The last glacial readvance took place about 13 000 years ago during the Port Huron Phase. The Halton Till was deposited over most of the area, with the ice margin reaching westward to just overtop the Niagara Escarpment. During its hesitant retreat, small moraines were formed (e.g., Cheltenham, Kelso and Trafalgar) and drainage was ponded in front of the ice to form glacial Lake Peel. Drainage of the higher land to the north and meltwater from the retreating ice formed deltas and varved clays in glacial Lake Peel.

The retreating ice eventually allowed drainage around its margin southward across New York State, and when a sill at Rome, New York, prevailed as water level control, glacial Lake Iroquois was formed. While outflow continued at Rome, isostatic tilting of the Lake Ontario basin caused the lake to transgress at its westward end; the Iroquois shore bluff and beach bars were formed about 12 500 to 12 000 years ago.

When ice retreat unblocked the St. Lawrence River valley, water levels dropped stepwise rapidly, leaving a large area of dry land in the western Lake Ontario basin, which was subsequently flooded during the ensuing thousands of years of isostatic tilting of the basin as Lake Ontario level was raised to the present. During this postglacial interval of over 11 000 years, the stream valleys of the Brampton map area developed their successions of terraces as streams cut down. At the same time residual depressions, such as kettle holes in the Brampton esker, accumulated peaty organic deposits, which recorded the changing plant and animal assemblages brought about by the warming climate. During this same time, the area became occupied by humans. Evidence of their prehistoric presence was found in the form of an Early Wood-

land projectile point (identified by C. Ellis, University of Waterloo) from a swamp near and northwest of Highway 401 and Kennedy Road (Photo 23).

ECONOMIC GEOLOGY

Aspects of Quaternary geology that are of economic importance in the Brampton map area are becoming more and more heavily dominated by land use and land-use planning. This is brought about by the rapid spread of urban growth westward from Toronto. As this happens, the situation with respect to mineral resources is rapidly changing. Extractable mineral resources are dwindling fast because urbanization seals off remaining deposits. Restrictive legislation often spreads in advance of urbanization thus inhibiting the continuation, expansion or development of new extraction sites. For the past 150 years, agriculture, which is dependent on the character of the soil, in turn dependent on its geologic history, has been the chief primary industry of the area. The rapid pace of urbanization is also ending agricultural land use. In the place of agriculture and extractive mineral land use, there has been a rapid growth in the need for information on the overburden for engineering purposes to support the construction of services and buildings for housing, business and industry.

Agricultural Soils

County soil surveys are available for all the study area that was not already urbanized at the time of soil mapping. Readers are referred to these reports for more detail on former Peel County (Hoffman and Richards 1953), former York County (Hoffman and Richards 1955), Wellington County (Hoffman, Matthews and Wicklund 1963) and former Halton County (Gillespie, Wicklund and Miller 1971). Only a few generalized comments are presented here.

There is generally a strong correlation between the geologic map units and the soils developed on them. Thus, Halton Till is the parent material for the major soil series developed on heavy-textured till: the Oneida clay loam (well drained); the Chinguacousy clay loam (imperfectly drained); and the Jeddo clay loam (poorly drained). Lake sediments east of Brampton from glacial Lake Peel have developed on them the Peel clay series (imperfectly drained). Areas of shallow drift or bare bedrock form the Brockport clay loam (well drained) and Cooksville clay loam series (imperfectly drained) on grey shale, or the Lockport clay (well drained) and Trafalgar clay series (imperfectly drained) on red shale. On the carbonate rocks west of the Niagara Escarpment, rocky and bouldery conditions are poorly suited to agriculture and are represented by the Farmington loam series. Sand plains formed as outwash, deltaic, river terrace and nearshore glaciolacustrine sands are the parent materials for the Fox sand or sandy loam (well drained) and the Brady sandy loam (imperfectly drained). These sand plains were formerly favoured for apple orchards, but most of this use has disappeared through urbanization.

Photo 23. Early Woodland projectile point found in a field near Highway 401 and Kennedy Road. (Actual size is approximately 7.3 cm.)

Sand and Gravel

The chief extractive mineral commodity of the area was sand and gravel. Individual operations were described by Hewitt and Karrow (1963) and Hewitt (1969). Many of these have since ceased operation and few remain active today. More recently, resources have been described in some detail for Caledon (OGS 1981; OGS and Golder Associates Ltd., in press), Milton (OGS 1982) and Halton Hills (OGS 1983; Golder Associates Ltd. and Rowell 1996).

Ice-contact (kame) sand and gravel remain a significant resource northwest of Georgetown and west of the Niagara Escarpment. However, because of the high content of siltstone and shale from east of and along the lower part of the escarpment, they are commonly of poor quality. Weathered shale and clay coatings are further causes for restricting the use of these gravels, although washing would help improve aggregate quality. Outwash gravels in the same area have been naturally washed and, although they too contain undesirable rock types, they have a wider range of aggregate uses than the kame gravels.

The Credit River valley upstream from Norval has been a productive source for gravel and sand, both younger and older than Halton Till. Where the till is present, stripping is necessary to reach the gravel. Most gravel pits in these deposits are now inactive or abandoned. Drilling and geophysical surveys might succeed in outlining additional buried deposits.

The Brampton esker, long a major gravel source, is now overwhelmed by the growth of Brampton (Photo 24), although a large portion of the gravel had been extracted. There could be lateral extensions, such as in the former gravel pit later landscaped to form Professor's Lake along the north edge of the map area (*see* Map 2223), but with so much urbanization of the area, these cannot be exploited.

Aggregate operations were formerly active along the glacial Lake Iroquois shoreline where gravel bars had developed. Few gravel pits were very large and all have long been closed down by urban encroachment. These

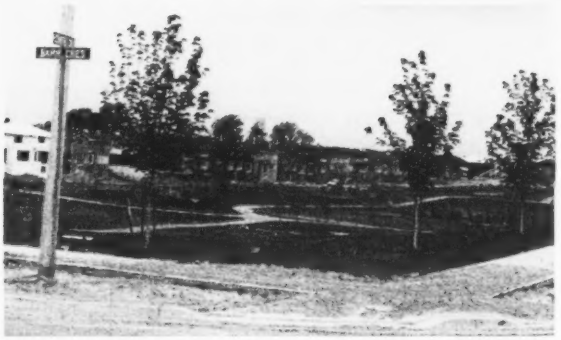

Photo 24. A former gravel pit, now covered by housing, situated on the Brampton esker, giving rise to the street name Esker Drive.

gravels were mainly composed of flaggy siltstone and also were of rather low quality, even though well washed by wave action. Thin beds of red clay were also noted by the author in 1957.

The area north of Milton is extensively underlain by a sand sheet. A few small aggregate operations have been worked where the sands come to the surface but the sand is generally fine and of limited use. Also, cover by a variable thickness of Halton Till impedes access to these deposits.

The glacial deposits of the Brampton area included the large boulder of Precambrian gneiss used to mount a plaque for an official ceremony in 1984 in front of the Parliament Buildings in Toronto (Photo 25), at which Queen Elizabeth II designated the white pine (*Pinus strobus*) as Ontario's provincial tree. The boulder was found at the surface near the limit of Halton Till west of Speyside.

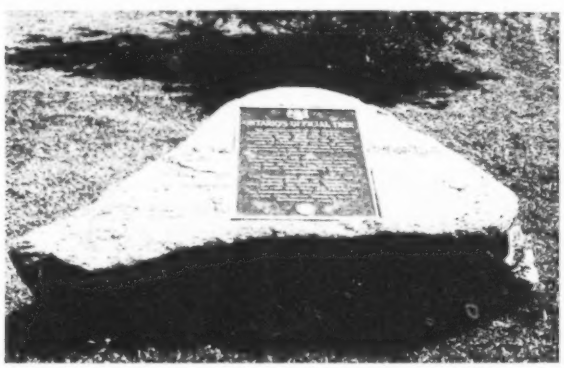

Photo 25. Boulder of Precambrian gneiss now located in front of the Parliament Buildings, Toronto, found west of Speyside, used to designate Ontario's official tree (white pine: *Pinus strobus*) in a ceremony at which Queen Elizabeth II officiated.

Water Supply

It might be assumed that with the rapid increase in population of the area, there would be a concomitant increase in the need to develop additional sources of groundwater. In fact, the growing network of the City of Toronto water system and other local systems that depend on Lake Ontario, has caused a lessening of the use of groundwater. This trend was already evident in 1947 and 1948 when Watt (1957, 1968) conducted surveys of the groundwater resources of former North York and Etobicoke townships.

More recent studies of water resources were undertaken for the Oakville (now Sixteen Mile) Creek basin by Ostry (1979) and by Funk (1979), and for the Region of Peel by Hickinbotham (1979).

Watt (1968, p.21) remarked that "A search for a high-capacity well in the township [Etobicoke] is, therefore, a search for the buried valley, which is more likely to contain well-sorted sands and gravels." Known locations of buried valleys have already been described (*see* "Bedrock Topography") but, given the uneven distribution of data on rock elevation, the detailed form and even some significantly large buried valleys probably remain to be discovered. Buried valleys with their common sand and gravel fills remain an important groundwater source, and such valleys are known to occur near the Humber River and Credit River valleys (the latter illustrated by Hickinbotham 1979) and Sixteen Mile Creek. The sediment fills of these valleys may include some of the oldest sediments of the area.

The buried sand sheet north of Milton shown by Funk (1979) is, stratigraphically, the next youngest. Both this and the buried valley aquifers are partly confined by underlying shale bedrock and overlying Halton Till, which are aquitards of low permeability.

Surface aquifers include areas of ice-contact sand and gravel, outwash sand and gravel, and glaciolacustrine sand. These are capable of supplying many domestic and farm needs, but suffer the ever-growing risk of surface contamination. Commonly, the water quantity in these aquifers is more limited than in the aquifers described above and suffers greater fluctuation with changing weather conditions.

The strip of land along the west edge of the study area underlain by the Silurian dolostone cap rock of the Niagara Escarpment is favourable for water supply from rock joints and bedding planes, although the water is hard because of dissolved carbonate. Wells in shale produce low yields, and not far below the bedrock surface the water is commonly strongly mineralized.

Peat

Peat extraction in the area is mainly for horticultural purposes and has mainly occurred sporadically, incidental to land clearing and excavation for urban construction. It was reported locally that the peat deposit near Eglinton Avenue West and Kennedy Road was formerly a commercial operation. When visited in 1987 during the course of this study, the only activity was by individuals coming to remove bags or baskets of peat for personal use. As previously noted, however (*see* "Organic Deposits"), a large volume of peat, probably from this site, had been stockpiled in an abandoned terrace gravel pit in southern Mississauga.

Clay

There is no record of clay deposits being mined in the Brampton map area for ceramic products. This is probably because of the accessibility of shale bedrock, which occurs at the surface or at shallow depth in many places. Nevertheless, glaciolacustrine clay of potentially suitable properties occurs over several parts of the map area. The most promising are the clays east of Brampton, although they are fast disappearing under urban construction. After testing, small-volume workings, such as for art pottery, might be supported by selected deposits.

Engineering Geology

There now exist many hundreds, or even thousands, of reports of engineering site investigations in this area of rapid population growth. Compilation of this large amount of information on the engineering properties of the materials of the area is of great potential value but is beyond the scope of the present project. Comments here are restricted to a few general observations made as a result of the mapping.

As part of the laboratory analysis carried out in support of the mapping, Atterberg limits were determined for most samples collected (*see* Appendix 4). Thus, 49 samples of Halton Till averaged a liquid limit of 23 (range 6 to 33%), a plastic limit of 16 (range 11 to 21%) and a plasticity index of 7 (range 1 to 13%). The coarser Newmarket Till (7 samples) averaged a liquid limit of 14 (range nonplastic to 22), a plastic limit of 11 (range nonplastic to 17) and a plasticity index of 3 (range 1 to 5). These deposits tend to low plasticity partly because of low clay content, but also because of predominantly inactive clay minerals (illite and chlorite, with little expanding clay mineral content). Halton Till varies from moderately soft when weathered or wet, to dense. Newmarket Till may be very dense to hard. All materials from the Halton Till downward, stratigraphically, have been preconsolidated by glacial overriding.

The fine sands and silts of glaciolacustrine origin may be frost-susceptible, and may yield troublesome quantities of water during excavation. Bank stability will also likely be a problem.

Overall, there are rather few engineering problems to be expected in the area. Although intensive construction activity could destabilize natural slopes, valleys indicate little trouble with landsliding. Very little of the lake shoreline has not already been stabilized with riprap and concrete structures, so there should be few shore erosion problems.

A potential problem that is arousing growing concern is the state of stress in the bedrock (White and Russell 1982), already described (*see* "Structural Disturbance"). Several sites of rock failure (pop ups, faults) were noted in the southeast part of the study area (*see* Map 2223) and puzzling features disturb the lake floor sediment surface offshore under Lake Ontario. Low-level seismicity in western Lake Ontario is becoming well documented (Wallach et al. 1993; Wallach, Mohajer and Thomas 1998). Potential damage to structures resulting from such activity needs further investigation.

Appendix 1: Descriptions of Measured Sections

Sections are listed in numerical order. "B" designated descriptions are those of Karrow (1960, 1984-87), Sharpe (1980) and Easton (1987). Others by Jones (1980) and Matthews (1977, 1978) are listed after. Authorship of "B" designated descriptions is indicated by initials in brackets, as follows: DRS – D.R. Sharpe; JAE – J.A. Easton; PFK – P.F. Karrow. Where measured by more than one author, the description is a synthesis of observations.

B-469 (DRS): East bank, Middle Sixteen Mile Creek, 2 km southwest of Hornby.

0 - 1 m:	Debris flow lacustrine facies.
1 - 2 m:	Halton drift. Interbedded silt till and stratified fine sand.
2 - 5 m:	Halton Till. Red-brown over grey gritty silt till.

B-474 (DRS): West bank, Middle Sixteen Mile Creek, 2 km southeast of Hornby.

0 - 1 m:	Sand. Medium, gravelly.
1 - 4 m:	Clay and silt. Rhythmites in upper part. Silt balls, pebbles, concretions.
4 - 6 m:	Covered to creek.

B-493 (DRS): East bank, Middle Sixteen Mile Creek, 0.5 km northwest of Drumquin.

0 - 0.5 m:	Sand. Fine to medium.
0.5 - 2.5 m:	Rhythmites. Silt and clay.
2.5 - 5 m:	Halton Till. Gritty silt till.

B-505 (DRS): East bank, Middle Sixteen Mile Creek, 0.5 km northwest of Drumquin.

0 - 0.5 m:	Sand. Fine to medium.
0.5 - 2 m:	Clay and silt. Laminated. Silt balls and pebbles.
2 - 5 m:	Halton Till. Red-brown over grey silt till.

B-507 (DRS): East bank, Middle Sixteen Mile Creek, 0.5 km southeast of Drumquin.

0 - 1.5 m:	Clay and silt. Pebbles and concretions.
1.5 - 5 m:	Halton Till. Silt till.

B-1014 (DRS, PFK): East bank, West Humber River, east of former Hwy. 27, 1 km north of Rexdale Boulevard.

0 - 3.7 m	Diamicton. Drab, olive-buff clayey silt with silt and clay clasts at intervals in bands. Scattered indications of layering. Carbonates on joints. Lacustrine. Sample A2 at 3.3 m.
3.7 - 6.6 m	Halton Till. Massive, olive-buff gritty clayey silt till to 4 m, grey below with oxidation along joints. Samples A and B of till. Sample B2 at 5.4 m.
6.6 - 8.1 m	Clay and silt. Faintly banded, with grits and pebbles. Cleaner downward with more obvious stratification near base. Sample C2 at 7.8 m.
8.1 - 12.9 m	Newmarket Till. Buff, hard stony sandy till. Parts oxidized orange. Sand lenses and layers. Grey near base. Sample C of till. Sample D2 at 8.7 m.
12.9 - 13.8 m	Shaly silt till. Lower part grades into a shale hash. Sample Y of till. Sample E2 at 13.2 m.
13.8 - 16.2 m	Georgian Bay Formation. Grey shale.

B-1018 (DRS, PFK): East bank, West Humber River, 2 km southeast of Claireville and 0.5 km southeast of Claireville dam. As of 1987 this section had a bridge on top of it and was totally obscured.

0 - 0.5 m:	Sand. Silty fine sand, few pebbles.
0.5 - 3.5 m:	Halton drift. Clay and silt. Some disturbed bedding, pebbles, fining upward. Layer of stony clay till (?) at 1.5-2 m. Sand layers near base are water bearing. Sample U of till.
3.5 - 9 m:	Newmarket Till. Sand till. Grey, hard stony sand till, coarser downward. Sample M of till.

9 - 11 m:	Sunnybrook Till. Clay till. Brown silty clay till, few pebbles. Scattered oblique sand stringers 7 cm thick. At south end replaced by shale bedrock. Thickens to 3 m at north end. Inclusion of detrital plant-bearing beds dated and analyzed for pollen by A. Dreimanis (see text), who reported an underlying older till unit as well. Sample L of till.

B-1019 (DRS, JAE): South bank, West Humber River, 0.5 km south of Humber College, 1 km west of former Hwy. 27.

0 - 1 m:	Silt and clay. Weakly banded, with grits. Thickness varies over irregularities in underlying surface.
1 - 2 m:	Diamicton. Gritty silt, abundant silt clasts (rounded to stretched).
2 - 2.7 m:	Silt and clay. Laminated and gritty, fining downward.
2.7 - 4 m:	Diamicton. Gritty silt, vague laminations, stretched silt clasts.
4 - 6 m:	Sand. Fine to medium, rippled, gravelly zones, grading to basal silt and clay.
6 - 12 m:	Halton Till. Gritty silt till. Sample.
12 - 14 m:	Covered to river.

B-1022 (DRS, JAE): South bank, West Humber River, 30 m east of former Hwy. 27.

0 - 1.8 m:	Silt. Brown over drab olive-buff, faintly banded with few clasts and clayey and sandy zones.
1.8 - 2.7 m:	Halton Till. Drab olive-brown silt till. Sample A. Sample A2 at 2.4 m.
2.7 - 3.6 m:	Silt. Faintly banded.
3.6 - 8.7 m:	Halton Till. Drab olive-brown silt till. Sample B.
8.7 - 9 m:	Sand. Orange-buff, medium grained. Wet.
9 - 9.15 m:	Sand. Grey, clayey and plastic, with pebbles.
9.15 - 10.15 m:	Newmarket Till. Grey stony sand till to water level. Sample C. Sample B2 at 9.45 m.

B-1023 (DRS, JAE): North bank, West Humber River, 100 m west of Kipling Avenue.

0 - 2 m:	Halton Till. Brown gritty silt till.
2 - 3 m:	Sand. Medium, water bearing.
3 - 6 m:	Silt till. Grey, gritty, hard.
6 - 7 m:	Sand. Coarse, cross-bedded, with gravel.
7 - 10.5 m:	Clay till. Grey, shale-rich silty clay till. Mostly covered to river.

B-1027 (DRS, Sado et al. 1984): South bank, West Humber River, at Claireville dam.

0 - 0.5 m:	Sand. Silty with diamicton layers.
0.5 - 3.5 m:	Clay, silt and sand. Fining upward, laminated. Basal sand water bearing.
3.5 - 6.5 m:	Halton Till. Gritty sandy silt till.
6.5 - 10.5 m:	Georgian Bay Formation. Grey shale.

B-1040 (DRS): West bank, Mimico Creek, 1 km west of former Hwy. 27 and 1 km north of Dixon Road.

0 - 5 m:	Halton Till. Brown gritty silt till.

B-1044 (DRS): West bank, Mimico Creek, 0.5 km west of former Hwy. 27 and 1 km north of Hwy. 401.

0 - 12 m:	Halton Till. Oxidized to 5 m. Gritty silt till.

B-1050 (DRS, PFK): East bank, Etobicoke Creek, 0.5 km north of Hwy. 401.

0 - 1.5 m:	Silt and sand.
1.5 - 2.5 m:	Clay, gritty.
2.5 - 5.5 m:	Halton Till. Gritty silt till. Sample A in middle of unit.
5.5 - 6 m:	Clay. Pebbles and grits.

6 - 7 m: Halton Till. Contains three boulder pavements; upper two striated at 150 to 160°. Sample B near base of the unit.
7 - 9 m: Newmarket Till. Silt till. Yellow sandy silt till with sand lenses. Sample C near base of exposure above road.

B-1069 (DRS): East bank, Humber River, 0.5 km south of Hwy. 401.
0 - 4 m: Sand. Yellow, silty, water bearing at base.
4 - 8 m: Silt till. Grey, massive.
8 - 16 m: Georgian Bay Formation. Grey shale to river.

B-1109 (DRS, JAE, DEJ): East bank, Credit River, 0.5 km northeast of main intersection in Glen Williams.
0 - 5 m: Halton Till. Sandy silt till with sand lenses.
5 - 7 m: Sand and gravel. Current to northwest.
7 - 11 m: Sand. Fine, ripple drift cross-lamination.
11 - 13.5 m: Silt and clay. Bedding distorted near base.
13.5 - 15.5 m: Sand. Some silt and clay.
15.5 - 17.5 m: Sand. Ripple drift cross-lamination.
17.5 - 24 m: Covered to river.

B-1179 (DRS, Sado et al. 1984): West bank, Etobicoke Creek, 0.5 km south of Hwy. 401.
0 - 5 m: Halton Till. Brown, pebbly.
5 - 6 m: Boulder concentration.
6 - 9 m: Halton Till. Grey, shale rich.
9 - 10 m: Georgian Bay Formation, folded (ice-thrust?).
10 - 11 m: Georgian Bay Formation. Grey shale and dolostone.

B-2288 (JAE): Road cut on 22nd Side Road, Concession 7, Esquesing Township (now part of Halton Regional Municipality), 300 m east of Credit River.
0 - 1 m: Halton Till. Silt till.
1 - 2 m: Sand. Medium.
2 - 3 m: Sand till. Silty.
3 - 5 m: Clay and silt, laminated.
5 - 6 m: Sand. Cemented at top.

B-2291 (PFK): West bank, Credit River, 1.5 km north of main intersection in Glen Williams.
0 - 3 m: Sand. Fine to medium. Boulders at base.
3 - 5 m: Silt till. Red-brown, stony; sand lenses in lower part. Sample near middle of unit.
5 - 8 m: Sand and silt. Stratified, grits and diamicton bands.
8 - 10 m: Clay. Grey, stratified, some grits and pebbles. To river.

B-2334 (PFK): West bank, West Sixteen Mile Creek, west of former Hwy. 25 and 0.5 km south of Derry Road.
0 - 1 m: Clay. Brown, gritty and pebbly.
1 - 2 m: Silt till(?) Red-brown clayey silt till. Sample A.
2 - 4 m: Halton Till. Brown gritty clayey silt till. Sample B.
4 - 12 m: Slump-covered to river.

B-2345 (PFK): East bank, east tributary of West Sixteen Mile Creek, 200 m south of Derry Road and 300 m east of former Hwy. 25.
0 - 2 m: Clay. Mottled grey and brown, gritty, laminated near base.
2 - 4 m: Halton Till. Red-brown gritty clayey silt till. Sample A.
4 - 4.5 m: Sand and gravel.
4.5 - 5.5 m: Covered.

5.5 - 7.5 m:	Silt till. Brown blocky clayey silt till. Sample B.
7.5 - 8 m:	Sand. Fine, stratified.
8 - 8.5 m:	Covered to stream.

B-2380 (JAE): East bank, East Sixteen Mile Creek, 1 km southeast of Drumquin.

0 - 1 m:	Sand, medium.
1 - 3.5 m:	Halton Till. Red-brown gritty clayey silt till.
3.5 - 6 m:	Silt till. Sandy.
6 - 8 m:	Sand and gravel. Diamicton layers.
8 - 9 m:	Covered to river.

B-2539 (PFK): Road cut on Mountainview Road south of Georgetown, south side of Silver Creek valley.

0 - 17 m:	Halton Till. Scattered exposures of brown sandy silt till.
17 - 20 m:	Silt. Laminated with 4 clay bands 7 cm thick, red top and bottom with white lime band in middle. Microlaminae in silt 2-3 mm thick and about 90 laminae in each silt bed (daily?).
20 - 20.3 m:	Cemented sand and gravel.
20.3 - 20.6 m:	Fine gravel.
20.6 - 29 m:	Covered to stream.

B-2579 (PFK): East bank, Middle Sixteen Mile Creek, 0.5 km northeast of Mansewood.

0 - 2.7 m:	Halton Till. Red-brown clayey silt till.
2.7 - 4.2 m:	Silt. Interbedded with sand near base.
4.2 - 9 m:	Covered to stream.

B-2633 (PFK): Georgetown. Factory excavation east of Mountainview Road on south side of River Drive.

0 - 2 m:	Halton Till. Red-brown silt till. Sample.
2 - 2.5 m:	Gravel. Medium to fine.
2.5 - 5.5 m:	Sand. Fine.
5.5 - 8.5 m:	Clay. Rhythmites.

B-2667 (PFK): East bank of Credit River at Norval, north of former Hwy. 7.

0 - 5 m:	Sand. Some gravel, stratified.
5 - 8 m:	Halton Till. Grey clayey silt till. Upper half faintly banded. Sample near middle of unit.
8 - 11 m:	Gravel. Medium to coarse, cemented.
11 - 23 m:	Covered to river. Scattered exposures of gravel.

B-2672 (PFK): East bank, Etobicoke Creek, east of Hwy. 10, 2 km northwest of Snelgrove.

0 - 1.5 m:	Halton Till. Brown gritty clayey silt till. Stratified clay and silt 7.5 cm thick at base. Sample A at 1 m.
1.5 - 3 m:	Halton Till. Brown gritty silt till. Sample B at 2.1 m.
3 - 5.5 m:	Clay till. Brown silty clay till.
5.5 - 7 m:	Clay and silt. Stratified.
7 - 7.5 m:	Clay till. Brown silty clay till as above. Sample C at 7.2 m.
7.5 - 8 m:	Clay and silt. Stratified.
8 - 11 m:	Covered to river.

B-2820 (PFK): East bank, Credit River, 1.5 km northwest of Meadowvale.

0 - 2 m:	Gravel. Medium to coarse, flaggy.
2 - 3 m:	Halton Till. Brown gritty silt till. Sample A.
3 - 4 m:	Clay, silt and sand. Laminated, rhythmites.
4 - 5 m:	Silt till. Brown gritty clayey silt till. Sample B. To river.

B-2931 (PFK) South bank, West Humber River, 2 km west of Claireville.

0 - 2 m:	Sand, silt and clay. Fining downward and grading to till below.
2 - 4.5 m:	Halton Till. Brown gritty clayey silt till. Fine sand lenses in lower part. Piece of black compressed wood on surface. Sample at 3 m.
4.5 - 5 m:	Sand and silt. Stratified and disturbed.
5 - 13 m:	Covered to lake level.

B-2965 (PFK): South bank, Etobicoke Creek, 200 m west of Dixie Road.

0 - 1 m:	Clay and silt. Thinly laminated with grits and pebbles. Diamicton layers in lower part.
1 - 5 m:	Halton Till. Buff to 3.7 m over grey gritty silt till. Sand and silt stringers in lower half. Sample A at 3.6 m. Sample B at 4.8 m.

B-2975 (PFK): North bank of Etobicoke Creek, 0.3 km south of Steeles Avenue and 0.4 km west of Kennedy Road, Brampton.

0 - 5 m:	Halton Till. Gritty silt becoming clayey downward.
5 - 7 m:	Clay. Till layers.
7 - 8 m:	Silt till. Brown gritty silt till. Grey zones.
8 - 10 m:	Sand. Gravelly and reddish in upper part.
10 - 12 m:	Covered to river.

B-2983 (PFK): West bank, Fletchers Creek, 100 m north of Derry Road.

0 - 1 m:	Halton Till. Strongly weathered.
1 - 1.3 m:	Sand. Fine, yellow.
1.3 - 6 m:	Halton Till. Brown gritty silt till, grey below 3.7 m. Sample A at 5.1 m.
6 - 10 m:	Covered to river. At north end small exposure at 8.3 m of stony sandy till. Sample B. Newmarket Till.

B-3001 (PFK) East bank, Credit River, 0.8 km southwest of Meadowvale.

0 - 1.5 m:	Gravel. Medium to coarse, rounded.
1.5 - 2.3 m:	Silt till. Brown over grey gritty silt till.
2.3 - 2.7 m:	Silt and clay. Grey, laminated.
2.7 - 4.2 m:	Silt till. Shale rich. To river level. Sample.

B-3003 (PFK): West bank, Credit River, 200 m south of Hwy. 401.

0 - 1.5 m:	Silt till. Brown gritty silt till.
1.5 - 2 m:	Silt. Laminated.
2 - 4 m:	Silt till. Brown gritty silt till.
4 - 5.3 m:	Covered to river.

B-3020 (PFK): West bank, Joshua's Creek, 100 m south of Dundas Street.

0 - 4.5 m:	Halton Till. Brown silt till. Silty clay inclusions in lower part - sample A at 2.4 m.
4.5 - 5 m:	Clay and silt. Stratified, with gritty layers.
5 - 8 m:	Silt till. Mottled red-brown stony silt till. Sample B at 6 m.

B-3035 (PFK): Service trench excavation, 1 km northwest of former Highway 5 and 0.5 km southwest of Winston Churchill Boulevard in Erin Mills.

0 - 3 m:	Red-brown silt till (Halton), grey in the basal 0.3 to 0.6 m.
3 - 4.0 m:	Grey silt and fine sand, well stratified, with dark organic streaks.
4.0 - 4.3 m:	Coarse gritty sand.

B-3102 (PFK): West bank, Credit River, 200 m south of Dundas Street at Erindale.

0 - 1 m:	Gravel. Cemented, rounded, medium.
1 - 7 m:	Silt till. Grey. Sample C.
7 - 11 m:	Sand. Gravelly and silty zones. Till lenses in lower part.
11 - 11.7 m:	Silt till. Grey. Sample B.
11.7 - 12.7 m:	Sand. Gravel and silt layers.
12.7 - 14 m:	Rubbly till. Abundant shale. Sample A.
14 - 18 m:	Georgian Bay Formation to Credit River.

B-3174 (PFK): East bank, Credit River, 300 m south of Eglinton Avenue.

0 - 4.5 m:	Sand. Brown, fine, silty. Water seepage at base.
4.5 - 5 m:	Clay and silt. Conglomeratic rhythmites.
5 - 7.5 m:	Silt till. Grey. Sample.
7.5 - 16.5 m:	Georgian Bay Formation to river.

B-3220 (PFK) South bank, Fletchers Creek, 1 km east of Meadowvale.

0 - 3 m:	Halton Till. Silt till.
3 - 3.6 m:	Gravel. Bedding contorted.
3.6 - 4.2 m:	Gravel. Cross-bedded.
4.2 - 4.4 m:	Sand and gravel.
4.4 - 5.4 m:	Silt. Bedding slopes to east.
5.4 - 7.4 m:	Covered to stream.

B-3288 (PFK): East bank, east tributary Etobicoke Creek, 2 km west of Terminal 1, Pearson International Airport.

0 - 1.5 m:	Silt. Clayey, over fine gravel; terrace deposit.
1.5 - 6.3 m:	Halton Till. Brown stony sandy silt till, grey below 3.3 m and poorly exposed to stream. Sample A near 2.5 m, sample B near 4 m.

B-3310 (PFK): Excavation for apartment building, north side of Burnhamthorpe Road east of Rockwood Mall.

0 - 1 m:	Silt.
1 - 2.5 m:	Halton Till. Brown silt till.
2.5 - 6 m:	Sand. Cross-bedded with gravel lenses.
6 - 8 m:	Till. Grey, shale rich. Sample. Newmarket Till.

B-4001 (JAE): West bank, Mimico Creek, 0.6 km northwest of Hwy. 401.

0 - 3.6 m:	Halton Till. Brown gritty silt till. Grey below 1.2 m. Sample A at 3 m.
3.6 - 9 m:	Silt till. Greenish gritty clayey silt till. Sample B at 4.5 m.
9 - 10.2 m:	Newmarket Till. Sand till. Stony, with sand stringers. Clay blebs in lower part. Sample C at 10 m.
10.2 - 10.5 m:	Sunnybrook Till. Clay till. Gritty silty clay till. Rubbly mixture at top. Sample D at 10.4 m.
10.5 - 11 m:	Covered to river.

B-4324 (JAE): West bank, Etobicoke Creek. 200 m south of Dundas Street.

0 - 1 m:	Sand. Poorly sorted, gravelly.
1 - 2 m:	Silt. Lower part laminated, gritty.
2 - 3 m:	Silt till. Brown gritty sandy silt till, grading coarser downward.
3 - 8 m:	Sand till. Grey, many sand lenses. Large body of gravel at 5 m thickens to north but sandy till is above and below it.
8 - 8.2 m:	Gravel. Fine.
8.2 - 8.5 m:	Georgian Bay Formation. Grey shale to river.

B-4325 (JAE): East bank, Humber River, 0.5 km southeast of CNR bridge at Weston.

0 - 2.5 m:	Sand. Medium.
2.5 - 5.5 m:	Silt and clay. Laminated.
5.5 - 6.3 m:	Silt till. Grey.
6.3 - 7 m:	Clay.
7 - 8.5 m:	Gravel. Poorly sorted, sandy, some boulders.
8.5 - 15 m:	Georgian Bay Formation. Grey shale to river.

B-4326 (JAE): East bank, Humber River, 300 m north of Albion Road bridge.

0 - 4 m:	Clay and silt. Gritty, silt clasts, rhythmites 2-3 cm thick. Unit thins to 1 m to south.
4 - 7.5 m:	Clay diamicton. Gritty silty clay.
7.5 - 12 m:	Mostly covered to river. Some grey gritty clay till.

B-4327 (JAE): West bank, East Humber River, 0.5 km east of Thistletown.

0 - 1.5 m:	Silt till. Brown clayey silt with flow structures.
1.5 - 2.5 m:	Clay. Interbedded debris flows and silt.
2.5 - 4.5 m:	Silt till. Grey, gritty. To river.

B-4328 (JAE): East bank, East Humber River, 200 m west of Islington Avenue. North edge of map area.

0 - 0.7 m:	Sand and gravel.
0.7 - 1.8 m:	Sand, silt and clay. Laminated.
1.8 - 3 m:	Sand and gravel. Clasts of clay and till.
3 - 5 m:	Clay, silt and sand. Clay layers, laminated. Clay and silt. Rhythmites, coarsens to sand at base. Beds contorted.
5 - 5.5 m:	Sand. Coarse and fine interbedded. Current to east.

B-4338 (JAE): East bank, Mimico Creek, 200 m east of Kipling Avenue.

0 - 2 m:	Halton Till. Brown gritty silt till.
2 - 4.5 m:	Sand till. Grey, stony, hard. To river.

B-4339 (JAE): East bank, Mimico Creek, south of B-4338.

0 - 0.5 m:	Silt. Sandy to gravelly.
0.5 - 4.2 m:	Halton Till. Brown gritty sandy silt till. Coarser at base.
4.2 - 5.5 m:	Silt and sand. Gravelly.
5.5 - 9 m:	Sand. Gravelly near top. Georgian Bay Formation at base at river.

J2 (Jones site #2): East bank, Credit River, at Glen Williams south of Wildwood Road.

0 - 6 m:	Silt till. Red-brown gritty sandy silt till.
6 - 9 m:	Silt and clay. Colour laminated, sand layers in lower part. Cemented at base.
9 - 12 m:	Sand. Medium, some pebbles.
12 - 17 m:	Covered to river.

J4 (Jones site #4): South bank, Credit River, 0.3 km south of CNR bridge. Drainage ditch, north edge of Georgetown.

0 - 1.2 m:	Clay till. Brown gritty silty clay till.
1.2 - 2 m:	Sand till. Red.
2 - 3.8 m:	Silt and clay. Laminated, pebbles in upper part.
3.8 - 5 m:	Silt till. Red-brown stony sandy silt till.

J5 (Jones site #5): South bank, Credit River, 0.5 km southwest of CNR bridge. Drainage ditch, north edge of Georgetown.

0 - 1.3 m:	Silt till. Red-brown gritty clayey silt till.
1.3 - 3.6 m:	Silt and clay. Laminated brown and red.
3.6 - 4.1 m:	Sand till. Red.
4.1 - 5.6 m:	Silt till. Red-brown gritty sandy silt till.
5.6 - 5.9 m:	Sand till. Red.
5.9 - 6.5 m:	Queenston Formation red shale.

MA (Matthews A): East bank, Fletchers Creek, 0.3 km north of CNR, west edge of Brampton.

0 - 1 m:	Diamicton and laminated clay.
1 - 6 m:	Halton Till.
6 - 8.5 m:	Covered to stream.

MB (Matthews B): West bank, Fletchers Creek, 0.5 km southeast of former Hwy. 7.

0 - 1 m:	Sand. Fine, stratified.
1 - 7.3 m:	Halton Till. Brown silt till, grey below 6 m.
7.3 - 9 m:	Covered to stream.

MC (Matthews C): West bank, Etobicoke Creek, west of Brampton Mall.

0 - 4.2 m:	Halton Till.
4.2 - 7.2 m:	Sand till. Red, stony.
7.2 - 9.7 m:	Covered to stream.

ME (Matthews E): East bank, Fletchers Creek, 200 m north of former Hwy. 7.

0 - 6.2 m:	Halton Till. Brown to 4.2 m over grey.
6.2 - 9 m:	Covered to stream.

MF (Matthews F): East bank, Etobicoke Creek, 200 m north of former Hwy. 7.

0 - 1.2 m:	Layered diamicton.
1.2 - 6 m:	Halton Till.
6 - 8 m:	Sand till.
8 - 9 m:	Covered to stream.

MK (Matthews K): East bank, Etobicoke Creek, 0.8 km northwest of former Hwy. 7.

0 - 2.5 m:	Diamicton. Silty. Rhythmites at base.
2.5 - 6.7 m:	Halton Till. Brown silt till.
6.7 - 9 m:	Queenston Formation red shale.

MM (Matthews M): East bank, Etobicoke Creek, 1.5 km northwest of former Hwy. 7.

0 - 1.5 m:	Diamicton. Silty. Contorted rhythmites at base.
1.5 - 6 m:	Halton Till. Silt till, brown to 3 m over grey.

MN (Matthews N): East bank, Fletchers Creek, 1 km northwest of Steeles Avenue.

0 - 4.5 m:	Halton Till. Red silt till.

MO (Matthews O): West bank, Etobicoke Creek, 1 km northwest of Steeles Avenue.

0 - 6 m:	Halton Till. Brown silt till.
6 - 8.3 m:	Sand till. Red-brown stony sand till.

Appendix 2: Logs of Cores from Holes Drilled for the Ontario Geological Survey

BH1: Milton, west end of Chisolm Drive, south of Hwy. 401.

0 - 0.9 m:	Disturbed top soil (silty loam, grey and buff). Reddish brown gritty clayey silt till; shale and siltstone clasts abundant; secondary carbonate in joints.
1.0 - 1.5 m:	No sample.
1.5 - 2.1 m:	Similar till, abundant carbonate on joints.
2.1 - 3 m:	No sample.
3.0 - 4.2 m:	Olive-brown gritty clayey silt till; stone content diminishes downward. 3 m: sample A - 10 YR 4/3*.
4.2 - 4.5 m:	No sample.
4.5 - 5.4 m:	Variously coloured (greyish, pinkish to olive) gritty clayey silt till; more stony than above. 4.8 m: sample B - 7.5 YR 4/2.
5.4 - 6.0 m:	No sample.
6.0 - 6.3 m:	Grey-red poorly sorted sand; upper 10 cm muddy sand.
6.3 - 7.5 m:	Red-brown gritty clayey silt till. Scattered larger pebbles starting at 7.5 m; grey zone at 6.75 m. 6.6 m: sample C - 10 YR 3/2.
7.5 - 8.3 m:	Same till; rounded, pebbly (up to 5 cm diameter). 7.8 m: sample D - 10 YR 4/2.
8.3 - 8.7 m:	Grey silt till; less stony, with large rounded pebbles (5 cm).
8.7 - 9 m:	No sample.
9 - 10.5 m:	Faintly colour banded, greyish and reddish brown and olive silt till (?); more plastic, softer than above. Rounded pebbles from 1-7 cm. 9.6 m: sample E - 10 YR 4/1.
10.5 - 12 m:	Same faintly banded till, perhaps waterlain.
12 - 13.2 m:	Greyish to pinkish brown clayey silt till; scattered rounded pebbles; banding near 13.2 m. 12.3 m: sample F - 10 YR 4/1.
13.2 - 13.5 m:	No sample.
13.5 - 15 m:	Greyish brown, stiffer, clayey silt till; banded at 13 m. 13.8 m: sample G - 10 YR 4/2.
15 - 15.5 m:	Reddish brown, gritty, clayey silt till. 15 m: sample H - 7.5 YR 4/2.
15.5 - 16.5 m:	Massive, brownish grey clayey silt, overlying a laminated clayey silt (16.2 m).
16.5 - 17.3 m:	Disturbed wet silt, grey.
17.3 - 17.6 m:	Pink-grey, muddy, medium gravel, medium sorting.
17.6 - 17.7 m:	Till-like, stony clayey silt.
17.7 - 18 m:	Banded clay and silt, red-brown to olive and grey; dropstones in upper part.
18 - 18.9 m:	Grey stratified silt and clay; fine sand at top.
18.9 - 19.5 m:	Red-brown with grey bands, laminated in clay and silt varves - 6 large units; colour-banded red and grey silt layers at 19 m.
19.5 - 20.6 m:	Red-brown laminated silt and clay; faulted clay layers; scattered dropstones.
20.6 - 21 m:	No sample.
21 - 21.9 m:	Grey-brown silt; disturbed. 21.3 m: sample I - 10 YR 5/2.
21.9 - 22.5 m:	No sample.
22.5 - 23.4 m:	Red-brown silt; disturbed. 23.1 m: sample J - 5 YR 4/3.
23.4 - 24 m:	No sample.

* Colour designations (e.g., 10 YR 4/3) according to Munsell soil colour charts, 1954, Munsell Colour Company, Baltimore.

24 - 24.6 m:	Grey-brown silt.
	24.3 m: sample K - 10 YR 4/2.
24.9 - 25.5 m:	No sample.
25.5 - 26.4 m:	Greyish brown, silty fine sand to fine sand.
	24.5 m: sample L - 10 YR 5/2.
26.4 - 27 m:	No sample.
27 - 27.3 m:	Muddy gravel and sand; red-brown remnant of till (?).
27.3 - 28.5 m:	Grey fine sand.
	27.5 m: sample M - 10 YR 4/2.

BH2: Esquesing Township (now part of Halton Regional Municipality), Fifth Line, 4 km south of Stewarttown.

0 - 1.2 m:	Brown gritty clayey silt till; topsoil in upper 0.3 m.
	0.9 m: sample A - 10 YR 5/3.
1.2 - 1.5 m:	No sample.
1.5 - 2.7 m:	Same till.
	2.5 m: sample B - 7.5 YR 4/4.
2.7 - 2.9 m:	Red-brown gritty silt till.
2.9 - 3.0 m:	No sample.
3.0 - 3.6 m:	Disturbed, crumbly stony sandy silt till. Red-brown.
	3 m: sample C - 5 YR 4/4.
3.6 - 4.5 m:	No sample.
4.5 - 5.3 m:	Stratified, red-brown silty fine sandy and clay bands; grades finer down into pinkish grey stratified silt.
6.1 - 7.6 m:	No sample.
7.6 - 9.2 m:	Red mudstone and green patches.

BH3: Esquesing Township (now part of Halton Regional Municipality), Fifth Line, 3 km south of Stewarttown.

0 - 1.5 m:	No sample.
1.5 - 2.1 m:	Red-brown dirty medium sand.
2.1 - 4.5 m:	Reddish brown fine sand.
4.5 - 6 m:	Red-brown silty fine sand.
6 - 7.2 m:	Grey-brown fine sand.
7.2 - 7.5 m:	No sample.
7.5 - 8.7 m:	Wet, grey-brown medium sand.
	8.4 m: sample A - 10 YR 4/3.
8.7 - 9 m:	Olive-brown silt and fine sand.
9 - 10.5 m:	Brown silty fine sand. Black specks (« 1 mm) possible organics.
10.5 - 11.9 m:	Olive-brown fine silty sand.
11.9 - 12 m:	Reddish brown silt.
12 - 13.5 m:	Red-brown to olive-brown silty fine sand with medium sand lenses on top and bottom; silt lenses at 12.9 m.
	12.6 m: sample B - 10 YR 4/3.
13.5 - 13.8 m:	No sample.
13.8 - 14 m:	Buff with red patches, medium to fine sand.
	13.1 m: sample C - 5 YR 3/4.
14 - 14.7 m:	Red-brown stratified silt; grey layer at 14.4 m.
14.7 - 15 m:	Grey gritty clayey silt till; large rounded stones.
	14.7 m: sample D - 10 YR 4/1.
15 - 15.3 m:	Disturbed; grey gritty silt till.
15.3 - 16.5 m:	No sample.
16.5 - 18 m:	Grey-brown sandy silt till; large pebble (8 cm). Rounded pebbles abundant. Lens of fine sand at 16.8 m.
	17.4 m: sample E - 10 YR 4/1.
18 - 19.5 m:	Same till.
	18.9 m: sample F - 10 YR 4/1.
19.5 - 20.1 m:	Grey-brown sandy silt till.
	19.8 m: sample G - 10 YR 4/1.

20.1 - 20.4 m:	Banded, grey-brown gritty silt and fine sand.
20.4 - 20.9 m:	Grey-brown gritty sandy silt till.
20.9 - 21 m:	No sample.
21 - 21.6 m:	Grey-brown sandy silty till. 21.3 m: sample H - 2.5 Y 4/2.
21.6 - 22.5 m:	No sample.
22.5 - 24 m:	Grey-brown sandy silty till. 23.4 m: sample I - 2.5 Y 4/2.
24 - 25.5 m:	Similar till; reddish brown.
25.5 - 26.3 m:	Olive-grey clayey silt till. 26.2 m: sample J - 10 YR 4/1.
26.3 - 26.7 m:	Grey-brown sandy silt till.
26.7 - 27 m:	No sample.
27 - 27.3 m:	Grey-brown gritty sandy silt till. 27.3 m: sample K - 10 YR 4/1.
27.3 - 28.5 m:	Grey, faintly stratified clayey silt; grits and dropstones. Glaciolacustrine; stratification improves downward.
28.5 - 28.8 m:	Grey gritty sandy silt; small pebbles. Disturbed and till-like; faint stratification.
28.8 - 29.4 m:	Laminated fine sand and clayey silt. Clay bands (5 cm) at 28.95 and 29.1 m.
29.4 - 30 m:	No sample.
30 - 30.1 m:	No sample.
30.1 - 30.3 m:	Varves(?); 15 grey clay to silt laminae; sharp contact at base of clay.
30.3 - 31.2 m:	Disturbed, red-brown and grey medium sand and void space.
31.2 - 31.3 m:	Red-brown fine sand.
31.3 - 31.5 m:	Dirty red-brown to grey-brown muddy fine gravel and clean coarse sand to fine gravel; grey.
32.1 - 32.7 m:	Clean coarse sand to fine gravel; mainly angular gravel.
32.7 - 33.6 m:	Dirty, grey fine gravel.
33.6 - 34.2 m:	Grey, clean coarse sand to fine gravel.
34.2 - 34.8 m:	Dirty, grey-brown fine gravel.
38 - 38.7 m:	Clean, grey coarse sand.
40.5 - 40.9 m:	Clean, grey coarse sand to fine gravel.
41.3 - 41.4 m:	Clean, grey fine sand.
41.4 - 44.1 m:	Fine sand; black specks common (probably inorganic).
44.1 - 44.4 m:	Red-brown clayey silt; possibly bedrock.

BH4: Chinguacousy Township (now part of Peel Regional Municipality), Mississauga Road, 4 km east of Terra Cotta.

0 - 0.3 m:	Black soil over olive gritty clayey silt (till?).
0.3 - 0.6 m:	Brown mottled gritty clayey silt till. 0.5 m: sample A - 10 YR 5/2.
0.6 - 3 m:	No sample.
3 - 3.5 m:	Grey silty clay to clayey silt, with grits and pebbles; massive to faintly laminated.
3.5 - 3.8 m:	Red-brown gritty sandy silt till; 5 mm grey fine sand at base. 3.6 m: sample B - 5 YR 4/3.
3.8 - 4.5 m:	No sample.
4.5 - 5.4 m:	Grey fine sand; disturbed at base. Grey and pale reddish brown stratified silt with grits and pebbles. 4.8 m: sample C - 10 YR 5/1.
5.4 - 7.5 m:	No sample.
7.5 - 8.1 m:	Reddish brown silty sand till (?). 7.8 m: sample D - 7.5 YR 5/2.
8.1 - 8.4 m:	7 cm fine gravel over fine silty sand.
8.4 - 9 m:	No sample.
9 - 9.3 m:	Red-brown stony silty sand till. 9 m: sample E - 7.5 YR 5/2.

BH5: Norval, south edge of Credit River valley, on upland.

0 - 0.6 m:	Disturbed topsoil over brown stony sandy silty till fill, over dirty coarse sand and fine gravel.
0.6 - 3.8 m:	No sample.
3.8 - 4.5 m:	Brown silt and scattered rounded pebbles. Lowest 2 cm is grey (till)? 4.2 m: sample A - 10 YR 4/6.
4.5 - 5.3 m:	Olive-grey stony sandy silt till. 5.1 m: sample B - 5 Y 5/1.
5.3 - 5.9 m:	Olive-grey stratified silt; dark olive-grey sand at base (1 cm).
5.9 - 6 m:	No sample.
6 - 6.9 m:	Loose, disturbed, dirty gravel at top, over olive-grey silt till. 7.2 m: sample C - 10 YR 4/1.
7.5 - 7.8 m:	Same till.
7.8 - 7.9 m:	Stratified clay and silt.
7.9 - 8.9 m:	Grey-brown gritty silt till. 8.4 m: sample D - 10 YR 4/9.
8.9 - 9 m:	Substratified grey-brown silt and till-rich zones.
9 - 10.5 m:	Grey-brown gritty silt till. 10.2 m: sample E - 10 Y 4/1.
10.5 - 11.9 m:	Grey-brown gritty silt till; scattered silt lenses and soft zones.
11.9 - 12 m:	Olive-grey gritty silt till; clay bands.
12 - 12.6 m:	Olive-grey gritty silt till. 12.3 m: sample F - 10 YR 4/1.
12.6 - 15 m:	No sample.
15 - 15.9 m:	Banded silt and fine sand; upper 60 cm massive. Grits and pebbles and clayey bands.
15.9 - 16.5 m:	No sample.
16.5 - 17 m:	Soft clayey silt; grits and pebbles; massive.
17 - 17.9 m:	Massive clean silty clay.
17.9 - 18 m:	No sample.
18 - 19.2 m:	Well-laminated silt and clay; grey with pink bands.
19.2 - 19.5 m:	No sample.
19.5 - 20.7 m:	Well-laminated clay and silt; grey and pink bands.
20.7 - 21 m:	No sample.
21 - 21.3 m:	Soft, grey and brown silt.
21.3 - 25.5 m:	No sample.
25.5 - 26.3 m:	Olive-grey laminated silt and clay.
26.3 - 27 m:	No sample.
27 - 27.8 m:	Laminated silt; grey-brown to olive-grey. Few grits and pebbles.
27.8 - 28.5 m:	No sample.
28.5 - 29.1 m:	Olive-grey to grey-brown banded silt; pebbles and grits.
29.1 - 30 m:	No sample.
30 - 31.2 m:	Olive-grey to grey-brown, weakly banded, gritty to stony clay and silt (waterlain till?).
31.2 - 31.5 m:	No sample.
31.5 - 32.7 m:	Olive-grey and pink-grey stratified silt and clay and scattered grits.
32.7 - 33 m:	No sample.
33 - 34.1 m:	Banded olive-grey and pink-grey, stratified clayey silt and silty clay; scattered pebbles.
34.1 - 34.5 m:	No sample.

BH6: Meadowvale Conservation Area, north of Derry Road.

0 - 1.5 m:	No sample.
1.5 - 2.7 m:	Olive sandy silt till; hard. 2.1 m: sample A - 2.5 Y 5/2.
2.7 - 6 m:	No sample.
6 - 7.2 m:	Soft, grey sandy silt till; upper 0.3 m is faintly banded. 7.1 m: sample B - 5 Y 4/1.
7.2 - 10.5 m:	No sample.
10.5 - 11 m:	Olive-grey, variable texture, disturbed silt till.
11 - 11.4 m:	Poorly sorted gravelly medium sand; olive-grey.

11.4 - 11.7 m:	Stratified fine to medium sand; olive-grey.
11.7 - 15 m:	No sample.
15 - 15.3 m:	Grey, compact, gritty silt till. 15.2 m: sample C - 10 YR 4/1.
15.4 - 15.6 m:	Disturbed muddy sand.
15.6 - 16.2 m:	Hard, olive-grey fine silt till; grades in colour from olive to dark grey. 15.8 m: sample D - 10 YR 5/1.
16.2 - 19.5 m:	No sample.
19.5 - 19.7 m:	Dirty fine gravel.
19.7 - 19.8 m:	Grey, disturbed silt till.
19.8 - 20 m:	Dirty, fine to medium gravel.
20.0 - 20.3 m:	Varied, disturbed, grey-brown stony sandy till. 20 m: sample E - 10 YR 5/1.
20.3 - 21 m:	No sample. Strong flow of artesian water.

Appendix 3: Locations of Sample Sites Other Than Those Described in Appendix 1

B-003: Road cut for Hwy. 401, 1.5 km southeast of Meadowvale.
3 m of brown fissile till (sample A) over 2 m of grey till (sample B).

B-004: Road cut for Hwy. 401 through Kelso moraine, west of former Hwy. 25.
Halton Till.

B-212: Road cut, Steeles Ave. W., 300 m northeast of Chinguacousy Rd.
1.5 m of Halton gritty silt till.

B-308: Road cut 3 km northeast of Hornby.
Sample A from lower sandy silt till and sample B from upper gritty clayey silt till in 2 m cut.

B-349: Road cut 1.6 km south of Ashgrove.
1 m cut in brown gritty silt till.

B-368: Road cut 1.5 km northeast of Mansewood.
2 m cut in brown gritty clayey silt till.

B-1008: Gravel pit face, 1.5 km northwest of Glen Williams.
Under 4.5 m of stratified sand, silt and clay is 1 m of sampled silty sand till.

B-2003: Former Milton Limestone quarry, northeast corner of Milton outlier.
Till pockets up to 3 m, sample at 2 m.

B-2031: Dufferin Aggregates quarry, 2.6 km northwest of Hwy. 401.
Pockets in rock irregularities are up to 2 m of stratified gravel, sand, silt and clay, over 0.5 m of sampled gravelly sand till.

B-2046: Road cut 2 km southwest of Speyside at west edge of study area.
1.4 m stony sand till.

B-2054: Ditch south of Hwy. 401, 0.5 km southwest of former Hwy. 25.
2 m of clayey silt Halton Till.

B-2132: Road cut 1.5 km northwest of Silver Creek near west edge of study area, in sandy till.

B-2188: Quarry 2.5 km southwest of Terra Cotta.
Sample at 2 m in 4.5 m face in red-brown sandy clayey silt till.

B-2235: Road cut 0.5 km west of Terra Cotta in clay till (?) with few stones.

B-2239: Road cut 2 km south of Cheltenham.
3 m cut in silty clay till.

B-2283: Road cut 1 km south of Terra Cotta.
6 m exposed clayey silt till. Sample A at 3 m in brown, sample B at 6 m in grey.

B-2383: Ditch cut, west bank of East Sixteen Mile Creek, at Drumquin.
1.5 m of gritty clayey silt Halton Till.

B-2548: Ditch excavation on Maple Ave., Georgetown.
Red-brown sandy silt till.

B-2568: House excavation on Mountainview Rd., Georgetown.
1.5 m excavation into brown fissile silty sand till.

B-2630: CNR cut north of Georgetown to 1.5 m in grey blocky clay till (?).

B-2632: Road cut, east side of Credit River valley north of Georgetown.
Sample of stony sandy silt till near base of slope under 6 m of surface clay till and a silt till.

B-2707: West bank of Fletchers Creek at former Hwy. 7.
2.5 m of gritty silt till (sampled) over 1 m silty sand.

B-2759: House excavation 0.5 km west of Huttonville, north of Credit River.
2 m of gravel and sand over 1.5 m laminated silt clay, over 1.5 m of sampled grey silt till.

B-2871: Water-main trench in Bramalea, 0.5 km northwest of former Hwy. 7.
Sample at 3 m of gritty silt Halton Till.

B-2882: Excavation south of Steeles Ave., Brampton.
Sample at 1.5 m in gritty clayey silt Halton Till.

B-2891: CNR cut north of Steeles Ave., Brampton.
Sample at 3.3 m in gritty clayey silt Halton Till.

B-2928: Excavation in TRCA Waterpark in Claireville Conservation Area.
Sample of silt till under 3 m of laminated clay.

B-2950: South bank of Mimico Creek in Malton.
Sample at creek level of sandy silt till. Newmarket Till.

B-2989: Former Canada Brick Company quarry, Streetsville.
Cut exposes 3.7 m of gritty silt Halton Till. Sample at 2.5 m.

B-3027: Road cut 4.5 km northeast of Drumquin.
1 m of brown stony silt Halton Till.

B-3030: Cut behind factory, 5 km east of Drumquin.
Sample at 1.5 m in 3 m cut in brown gritty silt Halton Till. At base, inclusions of sandy till and yellow silt.

B-3034: Water-main trench 6.3 km east-southeast of Drumquin to 3 m in red-brown clayey silt Halton Till.

B-3061: Sewer trench to 4.5 m, north side of Dundas St. in Erin Mills.
Sample of grey silt till from base of trench on spoil piles.

B-3069: West bank, Sheridan Creek, south of Dundas St.
Exposure 1 m of grey blocky silty sandy till.

B-3133: Lake Ontario shore bluff at Lorne Park.
Cliffs up to 15 m high, mostly covered. Sand over silt and clay over sampled stony silt till.

B-3212: Road cut 4 km northeast of Streetsville.
Sample at base of 2 m cut in olive gritty silt Halton Till.

B-3241: Excavation northwest of Dixie Rd. and Britannia Rd.
Trench to 2 m in olive gritty silt Halton Till.

B-3255: Excavation cuts south of Hwy. 401 and north of Eglinton Ave.
Sample of 1.2 m of olive gritty silt Halton Till over 2.2 m fine sand. Borehole reports show underlying gravel over silt till over bedrock at 10 m below exposure.

B-3261: Excavation south of King George St. in Weston shows 1 m sand over 1.5 m sampled clayey silt Halton Till.

B-3262: Apartment excavation east of John St., Weston.
Sample at 5 m below general level in sandy silt till.

B-3292: Excavation in roadway east of Pearson International Airport administration building.
Sample of grey silt till.

B-3303: Excavation, west side of Hwy. 10, north of Eglinton Ave.
3 m exposure of olive gritty silt Halton Till. Overlies sand in northeast corner.

B-3349: Former St. Lawrence Starch Company in Port Credit, excavation to 4.5 m in grey silt till.

B-3423: Sewer trench 1 km southwest of Hwy. 10 and southeast of Eglinton Ave., to 2.3 m in olive gritty clayey silt Halton Till.

Appendix 4: Analytical Results

Key to "Unit" codes: H – Halton Till; N – Newmarket Till; W – Wentworth Till; Sb – Sunnybrook Till; Y – York Till; GF – Glaciofluvial; L – Glaciolacustrine.

Field Station	Unit	Size			Carbonate		% Heavy Minerals	% Magnetics	Atterberg Limits		
		Sand (%) (2.0-0.062 mm)	Silt (%) (0.062-0.002 mm)	Clay (%) (<0.002 mm)	Total (%)	Calcite/ Dolomite Ratio			LL	PL	PI
B-003A	H	21	35	44							
B-003B	H	23	52	25							
B-004	H	13	43	44							
B-212	H	27	53	20	18	2.7	5.6	9.0	25	16	9
B-308A	H?	38	52	10	21	1.4			18	15	3
B-308B	H?	15	49	36	25	2.3			36	22	14
B-349	H	23	53	24	25	0.7			26	16	10
B-368	H	19	48	33	25	0.7			28	18	10
B-1008	H	25	65	10	32	1.3			16	15	1
B-1014A	H?	20	45	35	34	6.5					
B-1014A2	H	26	42	32	27	3.2					
B-1014B2	H	26	42	32	27	3.2					
B-1014C2	L	26	34	40	27	3.2					
B-1014B	H?	29	38	33	25	2.5					
B-1014C	N	45	47	8	21	1.1					
B-1014D2	N	56	39	5	26	2.7					
B-1014Y	Y?	41	44	15	14	1.5					
B-1018U	H?	18	37	45	26	5.0					
B-1018M	N?	43	40	17	20	1.8					
B-1018L	Sb?	4	56	40	13	1.8					
B-1019	H	35	45	20	26	1.8			16	11	5
B-1022A	H	18	47	35	27	2.5			29	17	12
B-1022A2	H	33	45	22	29	3.1					
B-1022B	N?	39	49	12	26	1.4			15	11	4
B-1022C	N?	36	54	10	28	1.1			13	12	1
B-1022B2	N	57	36	7	28	2.5					
B-1050A	H	35	50	15	16	4.1			23	15	8
B-1050B	H	35	48	17	8	2.0			22	16	6
B-1050C	N?	39	49	12	15	2.9			21	16	5
B-2003	H?	40	49	11	31	3.8					
B-2031	W?	60	35	5	37	1.8					
B-2046	W	58	37	5	58	0.3					
B-2054	H	21	58	21	24	1.8					
B-2132	W?	42	49	9	26	3.4	8.2	14.9	nonplastic		
B-2188	H	38	49	13	23	1.4					
B-2235	H?	4	49	47	22	1.7					
B-2239	H?	12	48	40	27	1.5					
B-2283A	H	26	54	20	28	2.3			22	16	6
B-2283B	H	22	53	25	26	1.1			20	14	6
B-2291	W?	37	52	11	32	1.8			nonplastic		
B-2334A	H	17	52	31	23	1.7			30	20	10
B-2334B	H	17	48	35	26	3.2			33	20	13
B-2345A	H?	32	54	14	20	2.2			22	17	5
B-2345B	H?	30	56	14	20	1.5			18	15	3
B-2383	H	31	51	18	19	2.3			24	17	7
B-2548	H	37	49	14	13	1.7			19	15	4
B-2568	H	49	44	7	29	2.0			nonplastic		
B-2630	H?	12	32	56	22	2.5			44	25	19
B-2632	W?	36	51	13	29	2.3			19	15	4
B-2633	H?	21	60	19	22	3.4			24	17	7
B-2667	H	16	61	21	21	3.2	4.7	5.4	26	17	9
B-2672A	H	23	52	25	16	1.9	4.6	8.8	30	17	13
B-2672B	H	31	52	17	22	3.2	4.5	6.6	21	13	8
B-2672C	H	11	63	26	29	2.3	4.2	7.7	28	17	11
B-2707	H?	32	54	14	19	5.1	4.4	7.9	21	14	7
B-2759	H	23	60	17	22	2.1	5.0	8.0	19	13	6
B-2820A	H?	32	51	17	16	3.3	4.2	8.5	24	15	9

Field Station	Unit	Size			Carbonate		% Heavy Minerals	% Magnetics	Atterberg Limits		
		Sand (%) (2.0-0.062 mm)	Silt (%) (0.062-0.002 mm)	Clay (%) (<0.002 mm)	Total (%)	Calcite/ Dolomite Ratio			LL	PL	PI
B-2820B	H?	23	49	28	19	2.7	2.9	7.4	30	18	12
B-2871	H?	27	50	23	22	4.3	4.0	7.5	23	15	8
B-2882	H	24	50	26	21	3.0	3.7	9.0	27	17	10
B-2891	H	26	51	23	29	6.5	3.4	10.2	23	15	8
B-2928	H	26	61	13	21	3.4	4.6	8.1	20	14	6
B-2931	H	24	55	21	22	2.9	6.7	8.1	23	14	9
B-2950	N?	40	48	12	23	1.0	4.9	8.0	15	12	3
B-2965A	H	37	49	14	20	1.7	3.9	8.0	18	13	5
B-2965B	H	32	50	18	22	1.1	4.0	8.3	19	13	6
B-2983A	H	32	51	17	21	1.7	4.0	7.6	18	13	5
B-2983B	N?	48	45	7	28	1.5	5.3	8.4	nonplastic		
B-2989	H	29	49	22	27	3.2	3.1	10.1	24	15	9
B-3001	H?	36	45	19	12	1.4	2.7	7.1	20	14	6
B-3020A	H	30	48	22	28	4.0			23	16	7
B-3020B	H	28	55	17	15	1.9			20	15	5
B-3027	H	28	50	22	19	9.0			28	18	10
B-3030	H	28	52	20	22	3.0			24	17	7
B-3034	H	29	46	25	20	2.7			24	16	8
B-3061	H	30	50	20	22	1.4			21	15	6
B-3069	H	8	68	24	29	3.0			26	18	8
B-3102A	H?	40	45	15	10	1.1			22	17	5
B-3102B	H	33	51	16	11	1.0			20	16	4
B-3102C	H	26	53	21	14	1.4			24	18	6
B-3133	H?	31	48	21	20	1.7			22	17	5
B-3174	H?	13	47	40	32	3.9			29	18	11
B-3212	H	23	54	23	20	3.3			26	19	7
B-3241	H	23	52	25	27	3.7			24	16	8
B-3255	H	30	54	16	14	2.1			22	17	5
B-3261	H	17	50	33	29	5.0			31	21	10
B-3262	H	13	57	30	32	9.4			26	18	8
B-3288A	H	34	48	18	17	2.8			21	16	5
B-3288B	H	35	50	15	15	1.6			17	14	3
B-3292	H	28	50	22	30	3.0			20	14	6
B-3303	H	37	46	17	18	2.0			21	15	6
B-3310	N	50	34	16	7	0.9			22	17	5
B-3349	H?	29	49	22	19	2.1			22	17	5
B-3423	H	16	57	27	19	2.5			28	20	8
B-4001A	H	31	49	20	28	2.9			21	14	7
B-4001B	H	29	49	22	32	2.0			18	13	5
B-4001C	N?	42	48	10	27	1.5			13	12	1
B-4001D	Sb?	21	49	30	22	1.4			23	15	8

Samples From OGS Boreholes

BH1

Sample	Unit	Size			Carbonate		% Heavy Minerals	% Magnetics	Atterberg Limits		
		Sand (%) (2.0-0.062 mm)	Silt (%) (0.062-0.002 mm)	Clay (%) (<0.002 mm)	Total (%)	Calcite/ Dolomite Ratio			LL	PL	PI
A	H	25	54	21	18	1.9	2.8	7.8	24	17	7
B	H	27	52	21	19	1.3	2.8	6.9	21	14	7
C	H	29	48	23	12	1.0	2.1	9.7	22	14	8
D	H	34	48	18	17	0.9	2.8	9.4	20	14	6
E	H	24	53	23	19	2.2	3.6	9.3	22	14	8
F	H	24	53	23	19	1.8	3.2	7.7	21	15	6
G	H	22	51	27	21	1.4	3.6	6.9	25	15	10
H	H	28	49	23	22	1.6	3.7	9.7	21	14	7
I	GF	14	82	4	21	1.3	2.9	6.9	nonplastic		
J	GF	9	85	6	24	1.6	3.1	7.0	nonplastic		
K	GF	82	17	1	21	1.1	2.6	4.4	nonplastic		
L	GF	5	91	4	24	1.0	3.5	7.6	nonplastic		
M	GF	86	12	2	20	1.3	5.6	6.5	nonplastic		

BH2

Sample	Unit	Size			Carbonate		% Heavy Minerals	% Magnetics	Atterberg Limits		
		Sand (%) (2.0-0.062 mm)	Silt (%) (0.062-0.002 mm)	Clay (%) (<0.002 mm)	Total (%)	Calcite/ Dolomite Ratio			LL	PL	PI
A	H	27	55	18	21	3.8	4.5	7.7	23	15	8
B	H?	40	48	12	29	3.7	5.9	9.0	15	13	2
C	H?	57	37	6	30	1.7	6.9	8.2	nonplastic		

BH3

Sample	Unit	Size			Carbonate		% Heavy Minerals	% Magnetics	Atterberg Limits		
		Sand (%) (2.0-0.062 mm)	Silt (%) (0.062-0.002 mm)	Clay (%) (<0.002 mm)	Total (%)	Calcite/ Dolomite Ratio			LL	PL	PI
A	GF	93	5	2	24	2.2	6.2	4.4	nonplastic		
B	GF	79	19	2	23	1.6	2.2	5.4	nonplastic		
C	GF	59	34	7	24	0.7	4.1	4.7	nonplastic		
D	H?	32	51	17	28	1.6	5.1	7.1	16	12	4
E	H?	33	51	16	25	2.4	5.4	6.4	17	12	5
F	H?	43	45	12	26	1.8	5.1	6.3	15	11	4
G	H?	33	51	16	26	1.6	5.6	7.3	16	11	5
H	H?	27	60	13	29	1.8	5.3	7.3	16	12	4
I	H?	31	56	13	27	2.6	5.1	9.3	16	12	4
J	H?	27	58	15	29	1.8	5.4	7.9	17	12	5
K	H?	31	54	15	21	2.3	4.8	6.4	16	12	4

BH4

Sample	Unit	Size			Carbonate		% Heavy Minerals	% Magnetics	Atterberg Limits		
		Sand (%) (2.0-0.062 mm)	Silt (%) (0.062-0.002 mm)	Clay (%) (<0.002 mm)	Total (%)	Calcite/ Dolomite Ratio			LL	PL	PI
A	H	24	52	24	26	3.1	4.6	8.6	23	15	8
B	H?	43	49	8	28	2.0	5.3	8.3	nonplastic		
C	GF	57	42	1	26	1.1	2.0	4.7	nonplastic		
D	W?	49	43	8	32	3.2	5.2	6.9	nonplastic		
E	W?	54	38	8	34	2.5	6.5	10.3	nonplastic		

BH5

Sample	Unit	Size			Carbonate		% Heavy Minerals	% Magnetics	Atterberg Limits		
		Sand (%) (2.0-0.062 mm)	Silt (%) (0.062-0.002 mm)	Clay (%) (<0.002 mm)	Total (%)	Calcite/ Dolomite Ratio			LL	PL	PI
A	GF	2	94	4	25	1.8			nonplastic		
B	GF	3	75	22	17	1.5			28	19	9
C	H?	26	50	24	20	2.1	4.4	8.9	21	14	7
D	H?	27	50	23	23	2.1	4.4	7.5	20	13	7
E	H?	29	49	22	20	2.9	4.0	6.1	20	13	7
F	H?	19	53	28	20	2.2	3.2	7.0	23	15	8

BH6

Sample	Unit	Size			Carbonate		% Heavy Minerals	% Magnetics	Atterberg Limits		
		Sand (%) (2.0-0.062 mm)	Silt (%) (0.062-0.002 mm)	Clay (%) (<0.002 mm)	Total (%)	Calcite/ Dolomite Ratio			LL	PL	PI
A	H	19	61	20	24	2.8	4.0	8.1	20	13	7
B	H	31	52	17	18	0.8	4.2	7.6	19	13	6
C	H?	30	48	22	25	2.9	5.0	6.3	18	12	6
D	H?	24	58	18	24	1.6	5.1	6.4	18	13	5
E	N?	57	37	6	27	1.4	6.7	9.6	nonplastic		

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Metric Conversion Table

Conversion from SI to Imperial			Conversion from Imperial to SI		
SI Unit	*Multiplied by*	*Gives*	*Imperial Unit*	*Multiplied by*	*Gives*
		LENGTH			
1 mm	0.039 37	inches	1 inch	**25.4**	mm
1 cm	0.393 70	inches	1 inch	**2.54**	cm
1 m	3.280 84	feet	1 foot	**0.304 8**	m
1 m	0.049 709	chains	1 chain	20.116 8	m
1 km	0.621 371	miles (statute)	1 mile (statute)	**1.609 344**	km
		AREA			
1 cm^2	0.155 0	square inches	1 square inch	**6.451 6**	cm^2
1 m^2	10.763 9	square feet	1 square foot	**0.092 903 04**	m^2
1 km^2	0.386 10	square miles	1 square mile	2.589 988	km^2
1 ha	2.471 054	acres	1 acre	0.404 685 6	ha
		VOLUME			
1 cm^3	0.061 023	cubic inches	1 cubic inch	**16.387 064**	cm^3
1 m^3	35.314 7	cubic feet	1 cubic foot	0.028 316 85	m^3
1 m^3	1.307 951	cubic yards	1 cubic yard	0.764 554 86	m^3
		CAPACITY			
1 L	1.759 755	pints	1 pint	0.568 261	L
1 L	0.879 877	quarts	1 quart	1.136 522	L
1 L	0.219 969	gallons	1 gallon	**4.546 090**	L
		MASS			
1 g	0.035 273 962	ounces (avdp)	1 ounce (avdp)	28.349 523	g
1 g	0.032 150 747	ounces (troy)	1 ounce (troy)	**31.103 476 8**	g
1 kg	2.204 622 6	pounds (avdp)	1 pound (avdp)	**0.453 592 37**	kg
1 kg	0.001 102 3	tons (short)	1 ton (short)	**907.184 74**	kg
1 t	1.102 311 3	tons (short)	1 ton (short)	**0.907 184 74**	t
1 kg	0.000 984 21	tons (long)	1 ton (long)	**1016.046 908 8**	kg
1 t	0.984 206 5	tons (long)	1 ton (long)	**1.016 046 90**	t
		CONCENTRATION			
1 g/t	0.029 166 6	ounce (troy)/ ton (short)	1 ounce (troy)/ ton (short)	34.285 714 2	g/t
1 g/t	0.583 333 33	pennyweights/ ton (short)	1 pennyweight/ ton (short)	1.714 285 7	g/t

OTHER USEFUL CONVERSION FACTORS

	Multiplied by	
1 ounce (troy) per ton (short)	31.103 477	grams per ton (short)
1 gram per ton (short)	0.032 151	ounces (troy) per ton (short)
1 ounce (troy) per ton (short)	20.0	pennyweights per ton (short)
1 pennyweight per ton (short)	0.05	ounces (troy) per ton (short)

Note: Conversion factors which are in bold type are exact. The conversion factors have been taken from or have been derived from factors given in the Metric Practice Guide for the Canadian Mining and Metallurgical Industries, published by the Mining Association of Canada in co-operation with the Coal Association of Canada.

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